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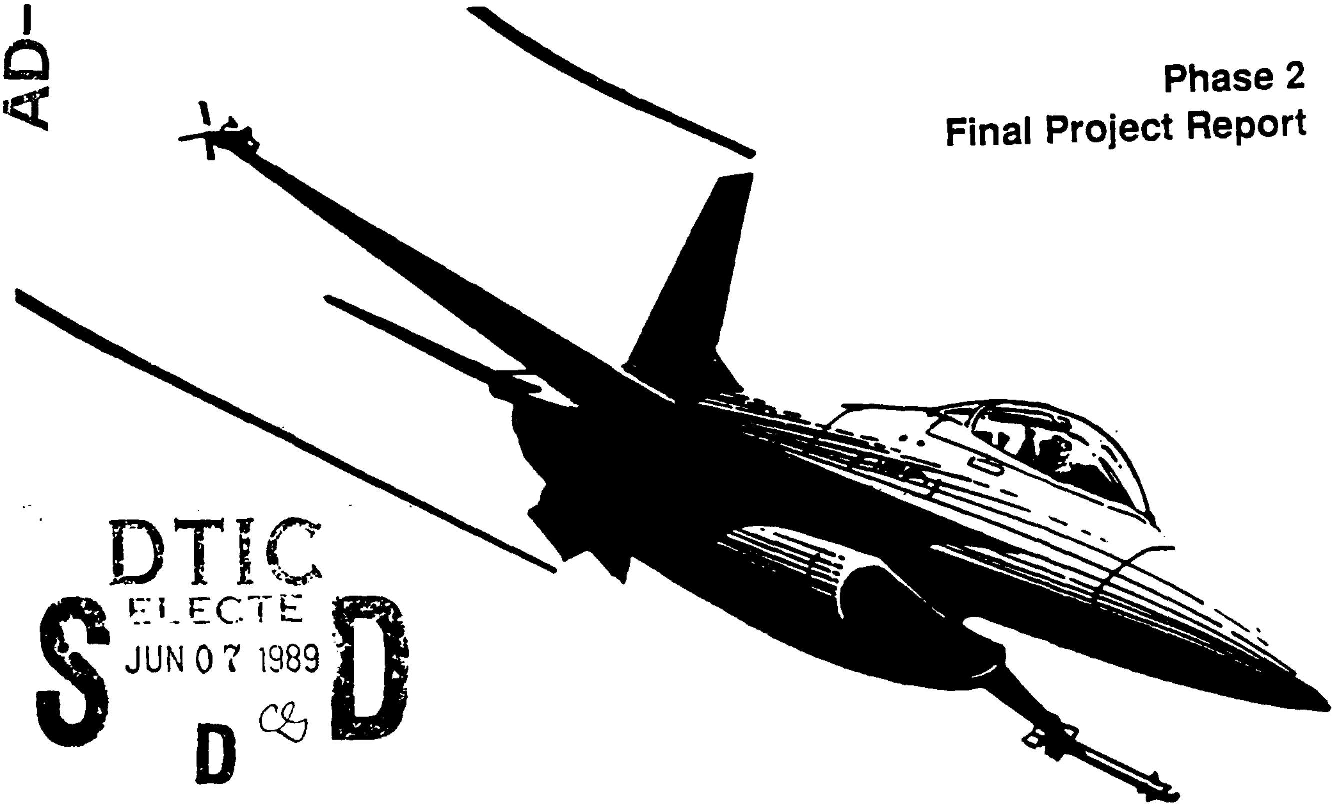
GENERAL DYNAMICS
FORT WORTH DIVISION

INDUSTRIAL TECHNOLOGY MODERNIZATION PROGRAM

Phase 2
Final Project Report



PROJECT 87

IMPROVE PROCESS AND AUTOMATE EQUIPMENT

REVISION 1

Honeywell
Military Avionics Division

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The modernization of the processes and equipment used in the chassis and transformer assembly and test areas is addressed in this project. This modernization will consist of an upgrading of manual assembly processes and methods, enhancements of test equipment and fixtures, automatic data recording, and the addition of automatic wire preparation. Incorporation of these changes will result in increased productivity and test yields through a reduction in rework, training, and throughput time.

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GENERAL DYNAMICS
FORT WORTH DIVISION

INDUSTRIAL TECHNOLOGY MODERNIZATION PROGRAM

PHASE 2 FINAL PROJECT REPORT

PROJECT 87

IMPROVE PROCESS AND AUTOMATE EQUIPMENT

REVISION 1

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PROJECT 87

TABLE OF CONTENTS

PROJECT 87
LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONTINUED)

PROJECT 87

IMPROVE PROCESS AND AUTOMATE EQUIPMENT

SECTION 1

INTRODUCTION

The Flight Management and Targeting Systems (FM & TS) Production Department is chartered to manage and produce a variety of fixed and rotary wing aircraft electronics in support of the Flight Systems Operation (FSO).

The mission of FM & TS Production is to generate revenue and profit by executing production contracts in support of FSO profit and ROI objectives. FM & TS products are typically low volume, high technology devices built under specific customer contracts. The area produces flight control and helmet sighting/display systems for fixed and rotary-wing military aircraft for various customers. Project 87 is concerned with the upgrade of processes and equipment used in the Transformer and Chassis assembly areas which are parts of FM & TS.

The Transformer Area may be thought of as a factory within a factory and functions as a service group which produces a variety of high-quality precision magnetics for FM & TS as well as for other groups within Honeywell. The assemblies are built to tight requirements meeting individual device needs. The group also builds engineering models for development programs. As a result, the Transformer Area produces a large variety of transformers making flexibility within the group a high priority.

The primary function of the Chassis Area is the production of chassis assemblies for the devices produced by FM & TS. Some work for the other groups within Honeywell is also performed but this is relatively limited in scope. The chassis assemblies, which are unique to each type, consist of a base plate, side and bottom panels, a front panel with I/O connectors and indicators of various sorts, and a heat sink panel on which high power dissipation components are mounted. Most of the device interconnections among the base plate and I/O connectors are done using semi-automatic wire wrap machines. The remainder of the interconnections are accomplished using solder techniques. The chassis also require various amounts of mechanical assembly such as riveting, staking, and screw/nut assembly.

Project 87 was initiated to provide increased efficiency by the use of modern assembly and test equipment improvements in the chassis and transformer areas within FM & TS. These improvements include:

- Chassis Area

    - Ergonomic workstation design
    - Machine group operations equipment
    - Wire wrap machine disk controller upgrades
    - Pneumatic powered torquing tools
    - Total Quality Control program

- Transformer Area

    - Improved ATE equipment
    - Ink jet marking
    - Oven monitoring network
    - Total Quality Control program

These improvements implemented under Project 87 will provide FM & TS with a significant increase in the efficiency of their manufacturing and help to reduce their overall manufacturing costs.

SECTION 2

PROJECT PURPOSE/OVERVIEW

The following section presents an overview of ITM Project 87. An overview of the FM & TS Production department and it's primary objectives is also presented along with a brief description of the Tech Mod efforts at Honeywell.

2.1 FM & TS Overview

Flight Management and Targeting Systems (FM & TS) Production is chartered to manage and produce a variety of fixed and rotary wing aircraft electronics in support of the Flight Systems Operation (FSO).

The mission of FM & TS Production is to generate revenue and profit by executing production contracts in support of FSO profit and ROI objectives. FM & TS products are typically low volume, high technology devices built under specific customer contracts. The FM & TS Production organization directly provides Production Engineering, Production Control, and operating capabilities to manage and execute production programs. support engineering programs, and provide specialized services to other product areas. Quality, Logistics, Procurement and Manufacturing Technical Services support is provided to FM & TS Production by Honeywell's Military Avionics Division (MAvD) central organizations.

The priority objective within FM & TS Production is to produce quality products within cost goals. Additional objectives include flexibility and dependability with the emphasis differing slightly in each of the focused factories.

2.2 FM & TS and Tech Mod

The USAF Tech Mod program was instituted to provide strategic planning and develop facility modernization projects that reduce manufacturing costs, improve product quality and reliability, and reduce manufacturing throughput time. In addition, the Tech Mod program has been chartered with assuring the capability for a rapid increase in production in the event of national emergency.

Under the guidance of the Tech Mod program, Honeywell has defined several areas for improving production in the Flight Management and Targeting Production facility in St. Louis Park, Minnesota. ITM Project 87 has been initiated with the purpose of upgrading the FM & TS Chassis and Transformer Production areas and is described in the following section.

2.3 Project 87 Strategic Goals and Objectives

FM & TS Production has defined several major objectives that are being incorporated in their future business planning. These objectives include increasing the flexibility of their operations and improving product quality, while maintaining a high degree of cost control.

Cost control is the overriding objective of FM & TS Production planning. This control must be maintained for both existing program production as well as for new programs. The cost control efforts underway in FM & TS Production are wide-ranging and are being applied at every level of the organization. Examples of this can be seen in the current implementation of the HMS/BOS MRPII system in St. Louis Park as well as the implementation of the Factory Data Collection System. In addition to controlling costs, the following objectives have been defined as critical to FM & TS's future production operations:

- **Increase flexibility of operations.** FM & TS will manufacture between six and ten products at any particular time and with the introduction of new programs which introduce both process and product changes, the current operations must remain flexible in adapting to these changes while still maintaining the capability of supporting existing programs.

- **Increase product quality.** By achieving 100% conformance with customer requirements, Honeywell will be viewed as the leading supplier of Military Avionics products. While this is of important strategic value from a marketing perspective, it can also have a direct effect on lowering the manufacturing costs in such areas as reducing rework and scrap.

- **Reducing production lead times.** Customer requirements dictate shorter production lead times and these will be accomplished through developing more streamlined process, material, and production flows. Improvements in information processing (such as HMS and FDC) will also aid in reducing production lead times.

ITM Project 87 has been defined by the Honeywell Tech Mod Project Team for implementation in Flight Management and Targeting Systems Production. This project, as defined by the Tech Mod Project Team, is described below.

ITM Project 87 addresses the modernization of the processes and equipment used in the chassis and transformer assembly and test areas within the FM&TS department. This modernization will consist of an upgrading of manual assembly processes and methods, enhancements of test equipment and fixtures, and automatic data recording. The benefits associated with the implementation of ITM Project 87 include:

- Improved testing of magnetics through automated test equipment
- Better assembly techniques through the use of pneumatically assisted fastening tools
- More productive chassis assembly functions through the introduction of modular, ergonomic workstations
- Legible, uniform marking of parts which reduces the marking process time
- Higher overall quality of product requiring less rework and resulting in less scrap
- Savings in quality costs through a trained and committed workforce
- Consistent, repeatable transformer testing processes
- Reduction in transformer testing set-ups
- Significant increase in productivity through application of a group technology approach to chassis assembly
- Better operator utilization through automated curing oven monitor
- Reduction in lead time to process chassis by incorporation of machine group processes
- Introduction of process equipment requiring lower skill to produce consistent, quality results

This project represents a significant part of the overall Tech Mod program currently being administered in Honeywell's Military Avionics Division.

SECTION 3

TECHNICAL APPROACH

The following subsections describe the general approach and methodology adopted by the Project 87 team for this project.

The first subsection describes the overall approach and methodology for performing an in-depth analysis of the FM & TS chassis and transformer area's operations and presents the methods employed in developing a structured design for more advanced operations. In addition, this section presents the evaluation methods used to establish technical requirements which define the areas for improvement within the Chassis and Transformer operations.

The second subsection introduces the philosophy of developing a manufacturing operations structure by first defining hierarchical levels employed in a manufacturing environment and the characteristics of production with respect to the impact of decisions concerning product versus process orientation (or a mix of these) at each of these levels. The ITM Project 87 objectives are then described as they relate to each of the hierarchical levels defined and the variables and criteria necessary for making recommendations for each of these levels is presented. These criteria are utilized more extensively in Sections 4 and 5 in defining and developing the advanced design of the transformer and chassis areas.

Subsection three presents the factors that affect the design of work areas (both work cells and workstations). The methodology of developing requirements for optimally designed work cells and workstations is presented along with the development of specific process requirements. Ergonomic design philosophies are described as they were employed in the development of the specific work stations as well as the overall area designs.

The final subsection describes the approach developed for selecting equipment. This includes the methodology used to develop requirements for equipment, the selection criteria, and the high level evaluation matrices.

3.1 Overview of Project Approach and Methodology

The project team has developed an overall approach for performing ITM Project 87 which is summarized in Figure 3.1-1. During the initial phase of the project, this approach required the collection of a great deal of information, including:

- Project 87 Statement of Work
- Tech Mod Program Goals
- FM & TS Business
- FM & TS Products
- Personnel Interviews

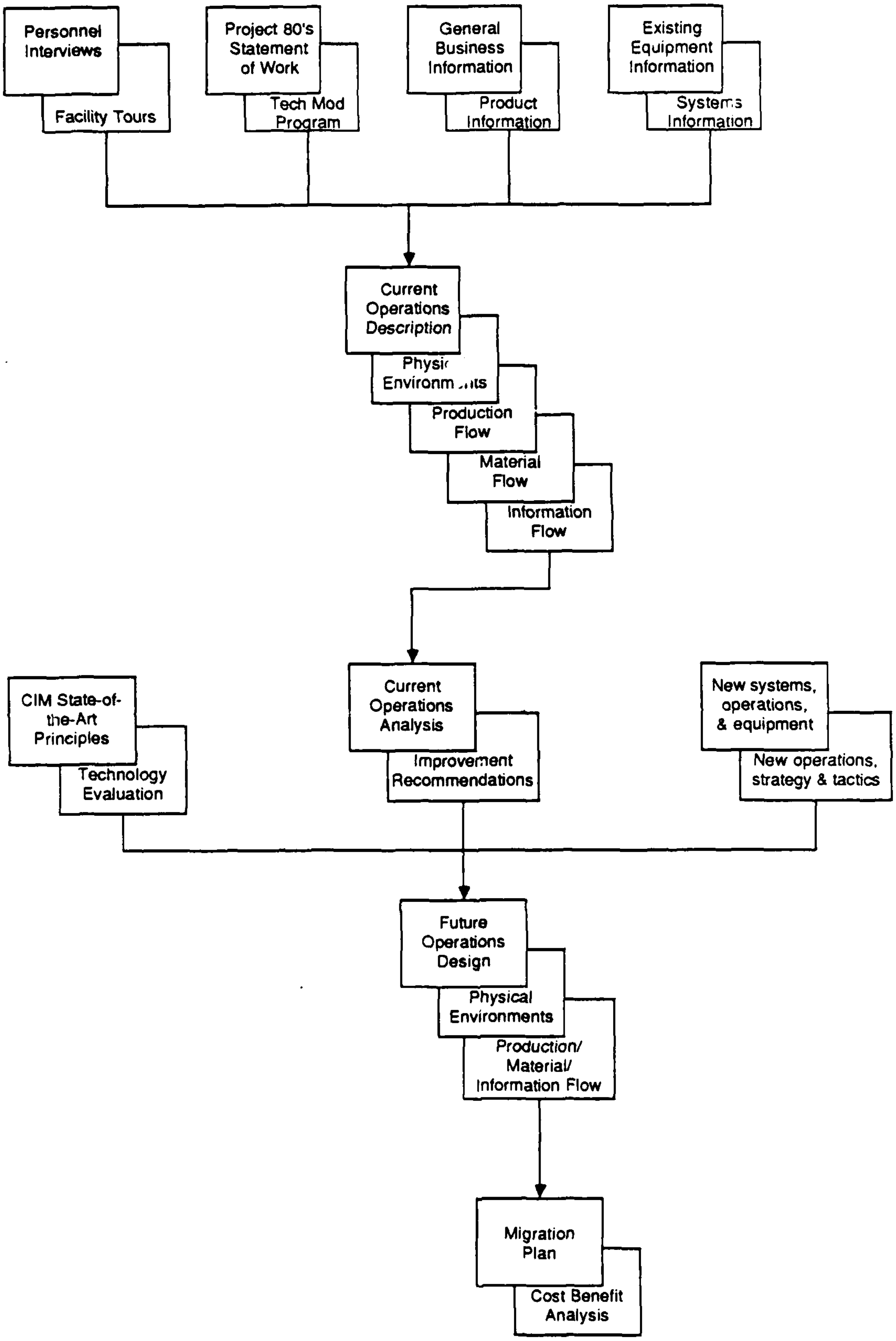


Figure 3.1-1 Project Approach and Methodology

- Facility Tours
- Chassis and Transformers Area Existing Equipment
- Chassis and Transformers Area Existing Systems

This information was assimilated by the project team and presented in a series of meetings designed to assure that the project team fully understood the various facets of the FM & TS Chassis and Transformer current operations. The analysis resulting from this exercise, along with the technological understanding of similar operations to that of FM & TS, were then utilized in developing the future operations design as well as the relayout of the area to provide a more streamlined production flow, material flow, and information flow.

The final phase in this process is the development of a migration plan which outlines the implementation steps required to achieve the final plan and a cost benefit analysis which defines the benefits in respect to the necessary investment and the time required to realize a return on Honeywell's investment.

In utilizing the approach described above, the project team has found that an iterative process methodology would yield the best results in the creative process of designing systems and operations similar to the FM & TS operations. This methodology is particularly applicable in the type of environment, both from a physical perspective as well as a business and management perspective, that exists for the Honeywell project team.

In the early stages of the project, the iterative process consisted of the presentation of information collected and assimilated by the project team in a concise format. After an agreement as to the adequacy of the presentation was reached at this level, the process moved further into more detailed levels. This is the basis of the iterative process. Further iterations addressed the first initial conceptual levels of design and, as more detail was agreed upon, more precise elements of the design were put into place.

The feedback generated as a result of each of these presentations and the incorporation of this information into the final report assures that the results of the overall design process are compatible with the desires and ideas expressed by the user's and management organization. The iterative design process is illustrated in a conceptual manner in Figure 3.1-2.

3.1.1 Operations Analysis

The goal of a comprehensive operations analysis is to first describe the current operations of Honeywell's FM & TS Chassis and Transformer areas. Based upon this description, specific areas and operations are defined (in accordance with the statement of work) for further analysis as they significantly impact the direct or indirect costs of FM & TS production. This analysis then provides the foundation upon which the operations of the future is designed.

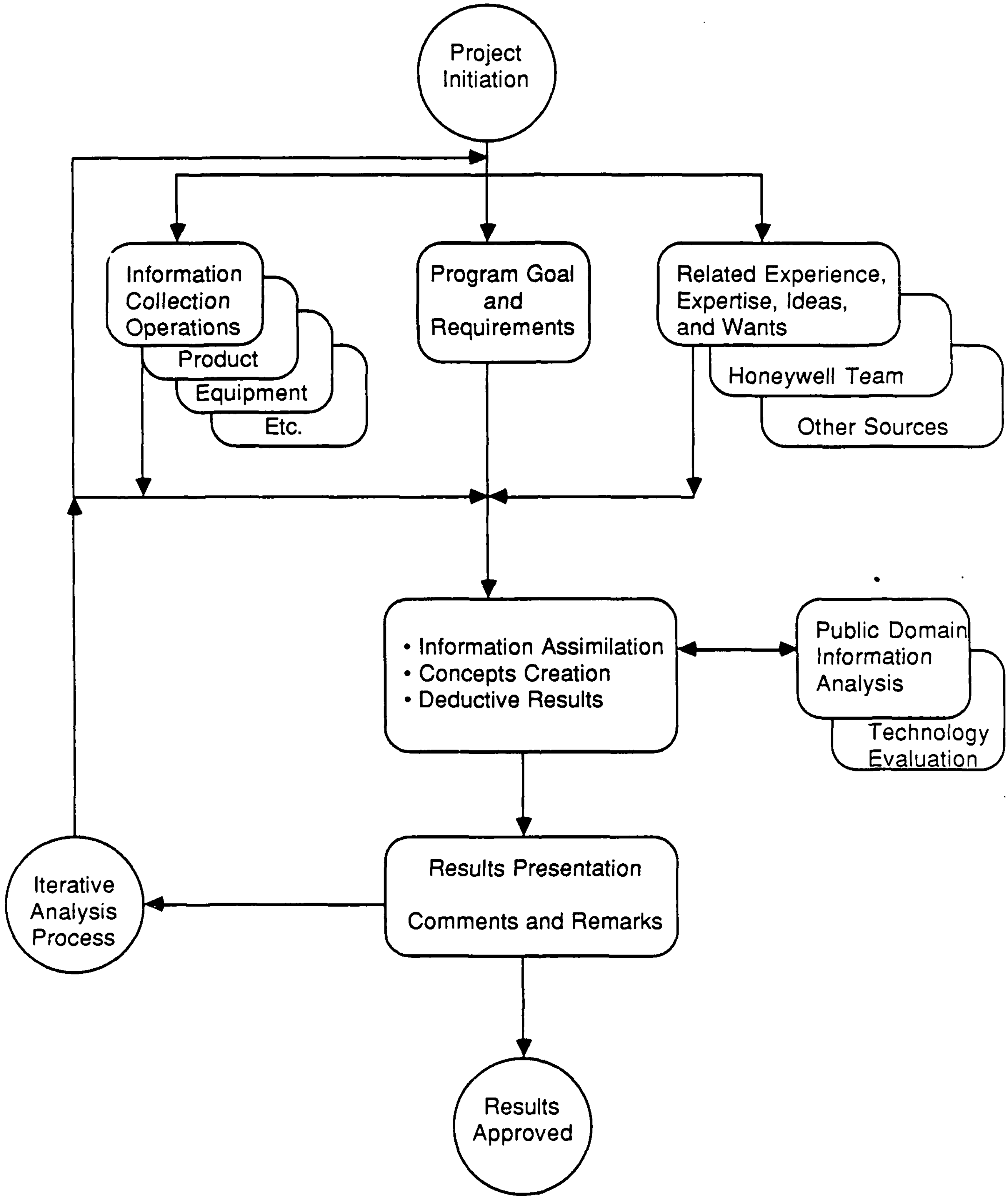


Figure 3.1-2 Typical Iterative Process

The absolute and definitive areas which are identified as cost drivers in the Transformer and Chassis operations lie in a multi-dimensional space with complex interrelated dimensions that are difficult to delineate. The primary task in the analysis phase is to determine the methods and approach required to define and analyze an issue which is extremely complex. As shown in Figure 3.1.1-1, this multi-dimensional space is characterized by the hierarchical levels existing within the FM & TS organization and the specific objectives of ITM Project 87.

By specifying the general objectives to be achieved, it is possible to reduce the complexity of these interrelated dimensions and to define objectives for each of the levels of operations and analyze improvements to be made at each level. Once these objectives have been defined at a specific level, it is then necessary to establish the significant variables and criteria that will influence the analysis and recommendations made for each of these levels.

While the variables and criteria are defined more comprehensively in Section 3.2.3, they are briefly summarized as:

- Production
  - Physical Arrangement
  - Process Flow
  - Group Technology
- Material
  - Material Management
  - Material Handling
- Information
  - Systems
  - Control Networks

In addition, several criteria have also been developed. These include such considerations as cost (capital investment, ROI, etc.) as well as product profiles and several other areas.

Once the project objectives have been finalized, the hierarchical levels defined, and the criteria and variables established, it is then possible to define the correlations between all of these dimensions and begin the structured design process as described in the following section and utilized throughout the progress of this report.

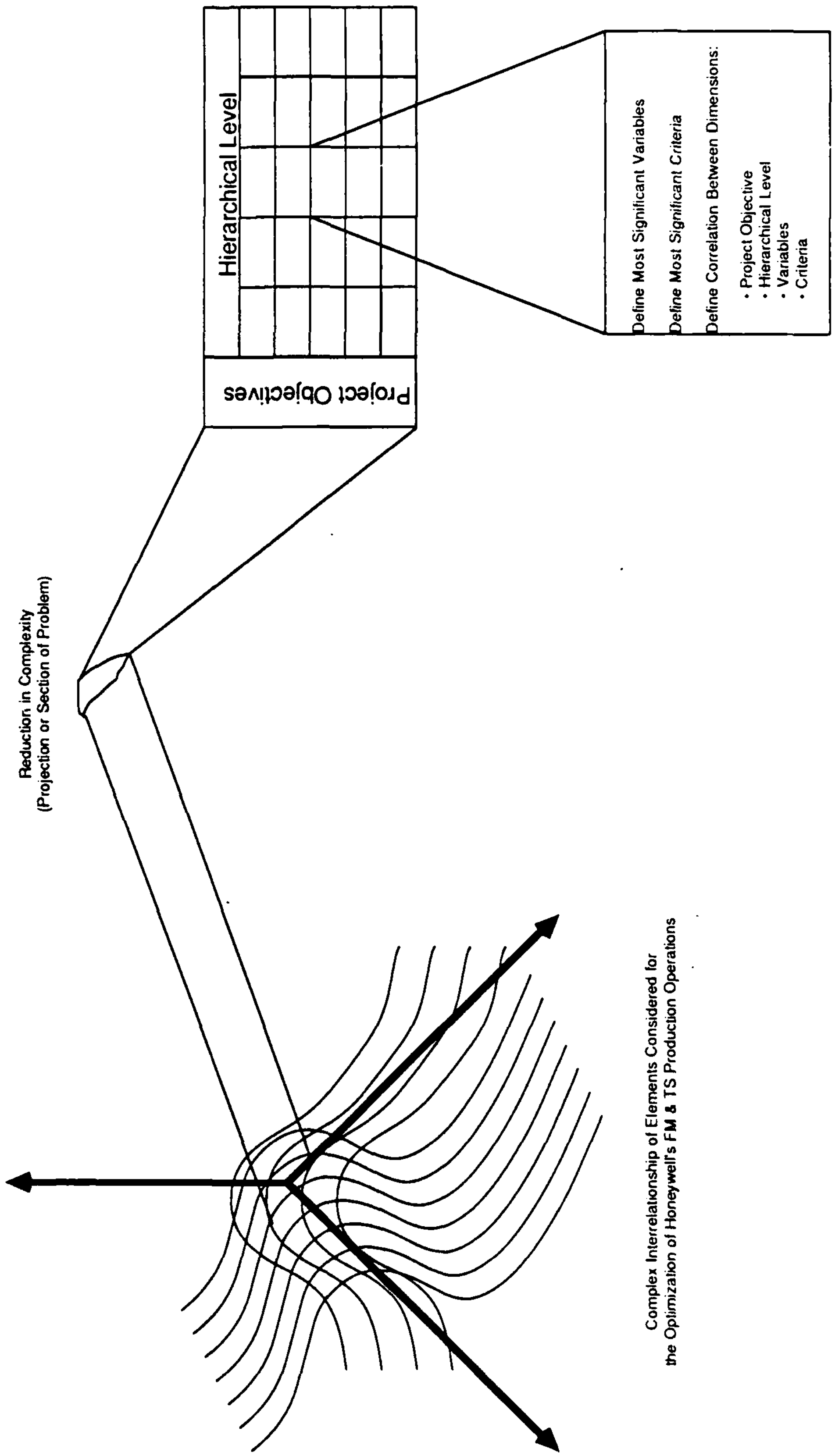


Figure 3.1.1-1 Multi-Dimensional Space Example

3.1.2 Structured Design Approach

The structured design approach employed by the project team is directly dependent upon a detailed analysis of the specific FM & TS operations for the transformer and chassis areas. The previous section described the methodology used to approach a large, complex, interrelated structure and "break down" that structure into discrete entities (i.e., work cells and workstations). Once the operations have been analyzed at a discrete enough level to understand the processes and unique characteristics at each level, it is possible to rebuild each of the levels progressively to transform the operations into a more advanced manufacturing structure.

A general overview of this "rebuilding" process is presented in Figure 3.1.2-1. Once the analysis phase has been developed to the workstation and process level, it is then beneficial to analyze each product and discrete process in respect to Group Technology. The term Group Technology has been alternately used to describe

1) a process of codifying parts in a computer database in order to group similar parts or

2) the organization of product families into cells in order to eliminate the duplication of resources.

A codifying of all parts used at Honeywell would be an extremely large undertaking and would require the coordination of several divisions to assure its effectiveness and to realize significant cost savings. While this would be a worthwhile endeavor for Honeywell, this was not a reasonable task for the implementation of ITM Project 87. However, the project team developed matrices to define the specific miscellaneous hardware used in the chassis and transformer areas as an aid in establishing proposed equipment and workstation requirements.

In addition, large scale matrices were developed which correlated the Honeywell part number (of each assembly, subassembly, and component part of all products produced by FM & TS) with the operations and the standard hours required to perform these operations. These correlation matrices provided important information for grouping similar processes at workstations, defining the equipment required at each specific type of workstation as well as the actual number of workstations required for each of these groupings of operations.

A number of other factors (which are primarily concerned with the overall area layout and the material handling requirements for these areas) have influenced the general workstation design requirements. The relationship of these factors to the overall design process is shown in Figure 3.1.2-2. The primary additional factors which also affect the design definition include:

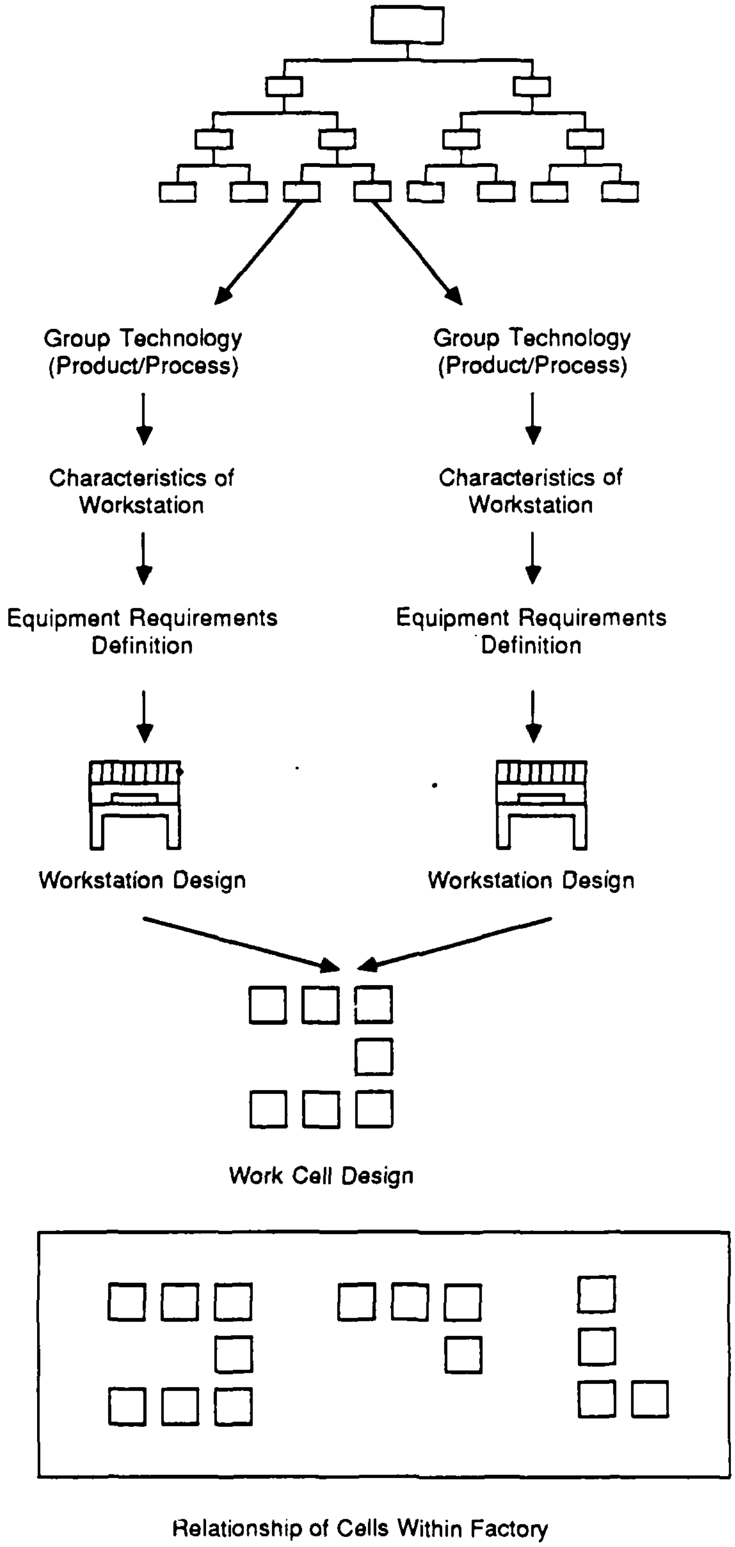


Figure 3.1.2-1 Overview of Methodology

- Production Volumes
- Material Movement and Transport Means
- Workstation Storage Requirements
- Work Area Storage Requirements

Once the design of new workstations, processes, and additional requirements for testing and other areas are defined, it is necessary to present specific technical solutions that can be implemented in the most efficient and effective manner.

3.2 Manufacturing Operations Structure

The manufacturing operations in Honeywell's FM & TS Production area have been structured both to reflect an overall Honeywell approach to divisional responsibility and in response to the changing product and production requirements. In order to develop the optimum manufacturing solutions for FM & TS production, it is necessary to "break down" the manufacturing operations structure into more discrete entities or levels that can be analyzed separately before "restructuring" the operations to provide a global alternative to their current operations.

Once these levels have been defined, a trade-off analysis can be made regarding production principles at each of these levels and for the effect the characteristics of these principles have at each of the levels and the sub-groups within these levels. The primary production principles described in this section can be defined in terms of either product orientation or process orientation.

The analysis of the operations structure is applied to the specific objectives of ITM Project 87. This provides an assessment of the impact of these principles at each level addressed by the project and defines the project objectives with respect to each level.

Following the detailed definition of the project's objectives, the specific variables that influence decision making at each of the levels and the criteria that must be met to accomplish the project objectives are determined. The variables can be defined as global considerations for developing cost drivers for the overall project. The criteria then provide the specific elements which must be evaluated for specific ROI and payback analysis that will determine the justifiability of each of the improvements recommended.

3.2.1 Definition of Hierarchical Manufacturing Levels

The current trends in analyzing manufacturing operations structures is to view the manufacturing structure in a hierarchical manner. This approach provides the basis for determining the ways in which manufacturing is performed as well as the influence of the structure on the actual manufacturing operations.

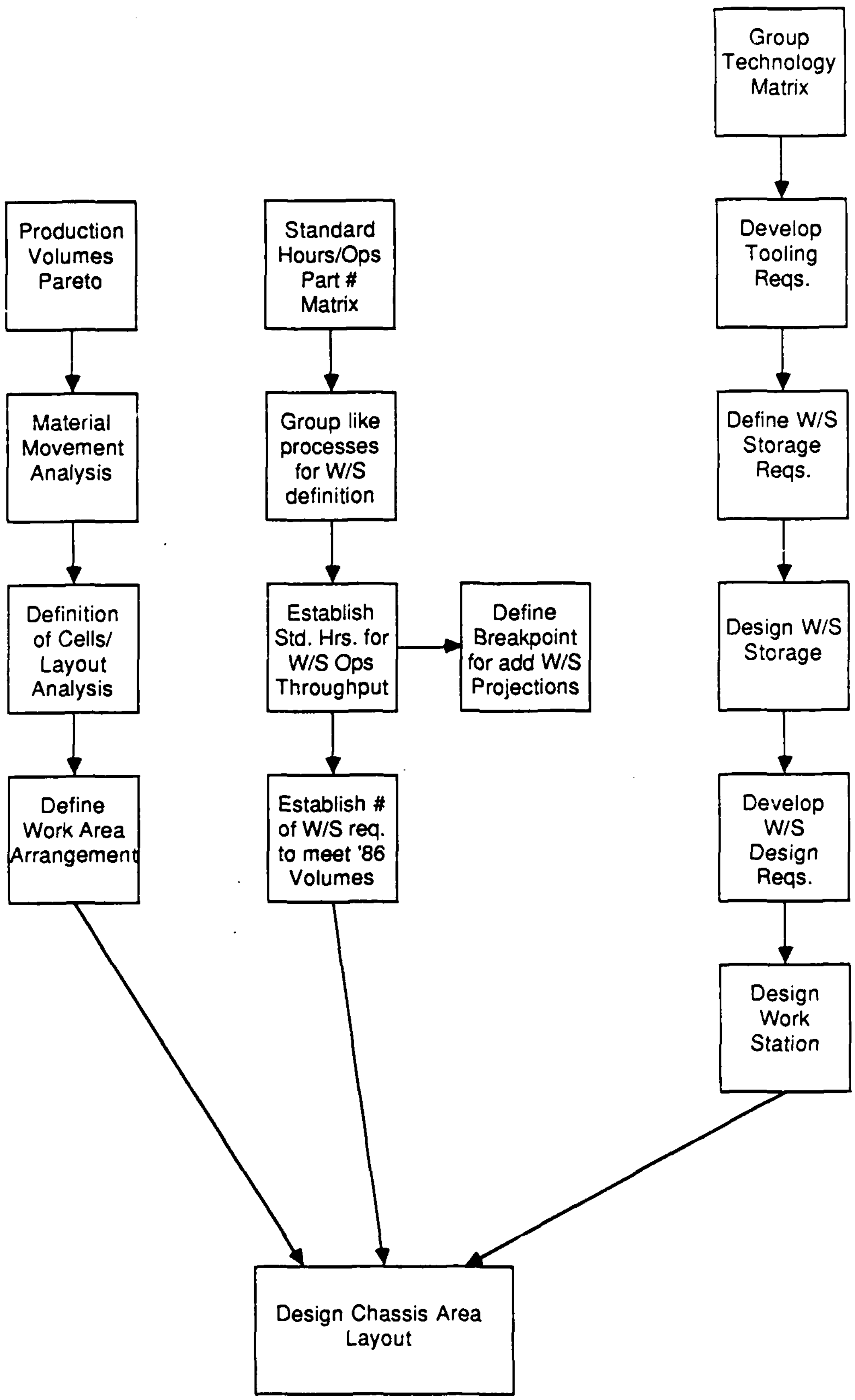


Figure 3.1.2-2 Development of Chassis Area Layout

The primary divisions that are typically defined are:

- Company
- Division
- Factory
- Work Center
- Work Cell
- Workstation/Process

Each of the hierarchical levels below the Division level is described in detail in the following paragraphs. While some of these descriptions may imply computer controlled actions at each level, these actions are actually possible either through a computer control system or through a manual "paper-based" system. Subsequent sections (Sections 4 and 5) define each of the hierarchical levels as they apply to the current FM & TS operations and the proposed FM & TS manufacturing operations respectively.

Factory

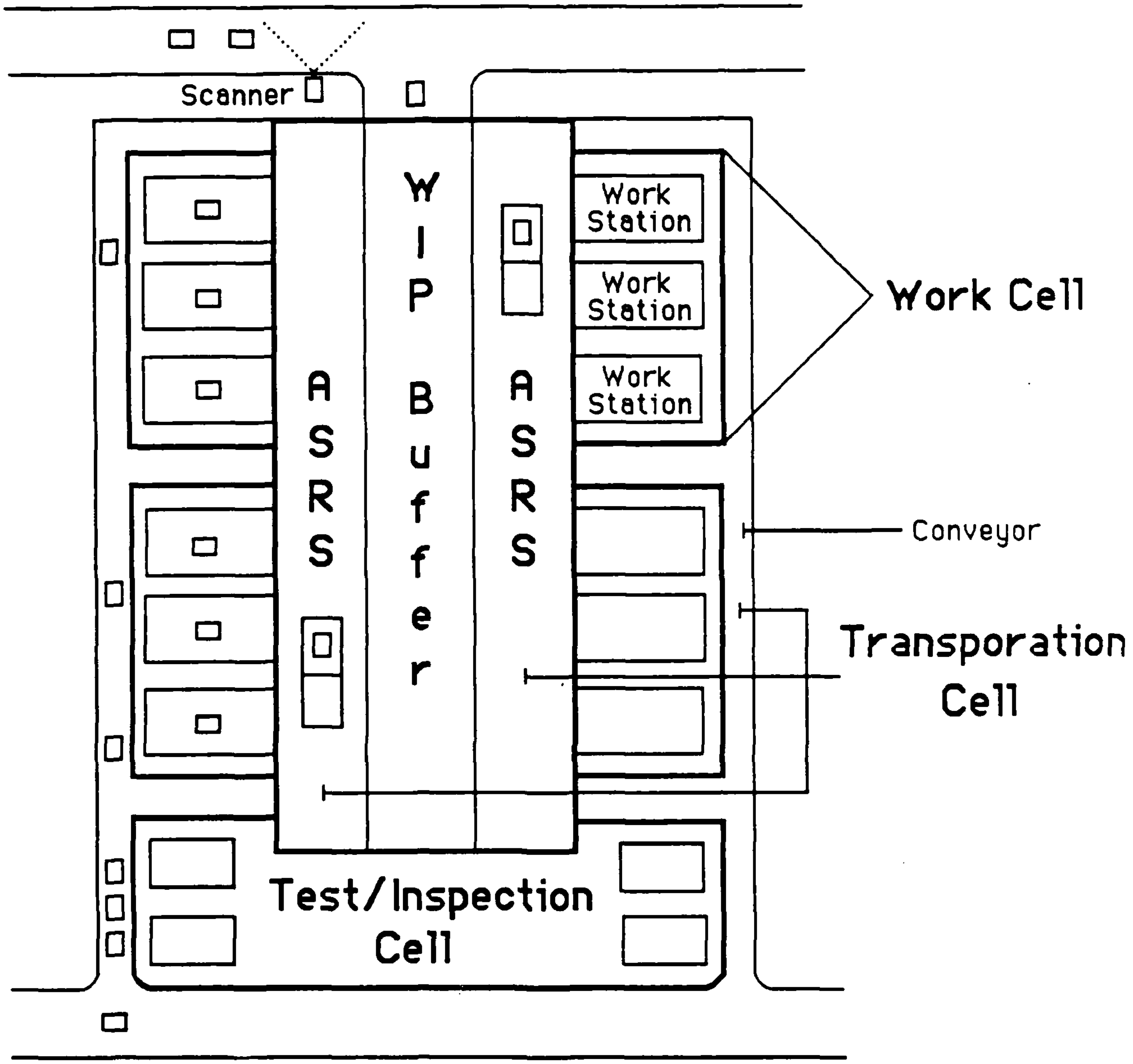
The factory level (also known as the plant level) is responsible for all production operations for a related set of products. In response to divisional or corporate forecasts, the factory develops a manufacturing resource plan to achieve these goals. In addition, the factory is responsible for monitoring the overall efficiency and productivity of the manufacturing resources.

Included within the factory are the shipping and receiving functions, warehousing, administration and manufacturing services, data processing, and the entities which are responsible for the production processes.

From a systems perspective, the factory level is where MRP (Material Requirements Planning) or MRP II (Manufacturing Resources Planning) systems reside. These types of systems take a macro view of the production operations as an integral part of the entire operation of the factory. Production and the processes entailed are viewed from this level as financial entities and therefore, the most important information required at this level is the rate of production, inventory levels, production completions, and other financial related data.

Work Center

The work center level (which is shown conceptually in Figure 3.2.1-1) is responsible for the production of a specific product line or a set of related subassemblies or products. In a general view, the work center is responsible for coordinating the actual manufacture of a product involving all of the required processes and procedures.



Responsible for production of a specific product line or set of related subassemblies

Optimizes near-term resource schedules to meet factory production plans (specific resource allocations)

Authorizes actual manufacture of products associated with the work center

Monitors performance and near-term availability of work center resources.

Figure 3.2.1-1 Work Center

To meet production objectives, the work center is responsible for a greater range of tracking production than a units/time period level. The work center allocates specific resources and provides near-term scheduling to meet the overall factory production plans. In performing this, it is responsible for authorizing the actual manufacture of products, the release of materials to the manufacturing floor, as well as the transference of product from manufacturing to shipping.

The work center is also responsible for monitoring the performance and near-term availability of work center resources. These resources include inventory levels and replenishment, material transfer and transportation means, processes, in-process storage, and several others.

Work Cell

The work cell (whether physical or logical) is responsible for performing a specific set of related operations or factory services. This can be defined as a specific subassembly or a specific process required by all subassemblies or assemblies. The work cell is also responsible for coordinating all activities among the workstations within the cell. This includes authorization of workstation activation and deactivation, tool changes, intra-cell material handling, and other inter-station activities.

The work cell also monitors at a discrete level each of the workstations within the cell as far as exact location and current process being performed. With this data, the work cell can then direct corrective action with respect to exception conditions at workstations or can notify the local operator as to a required action.

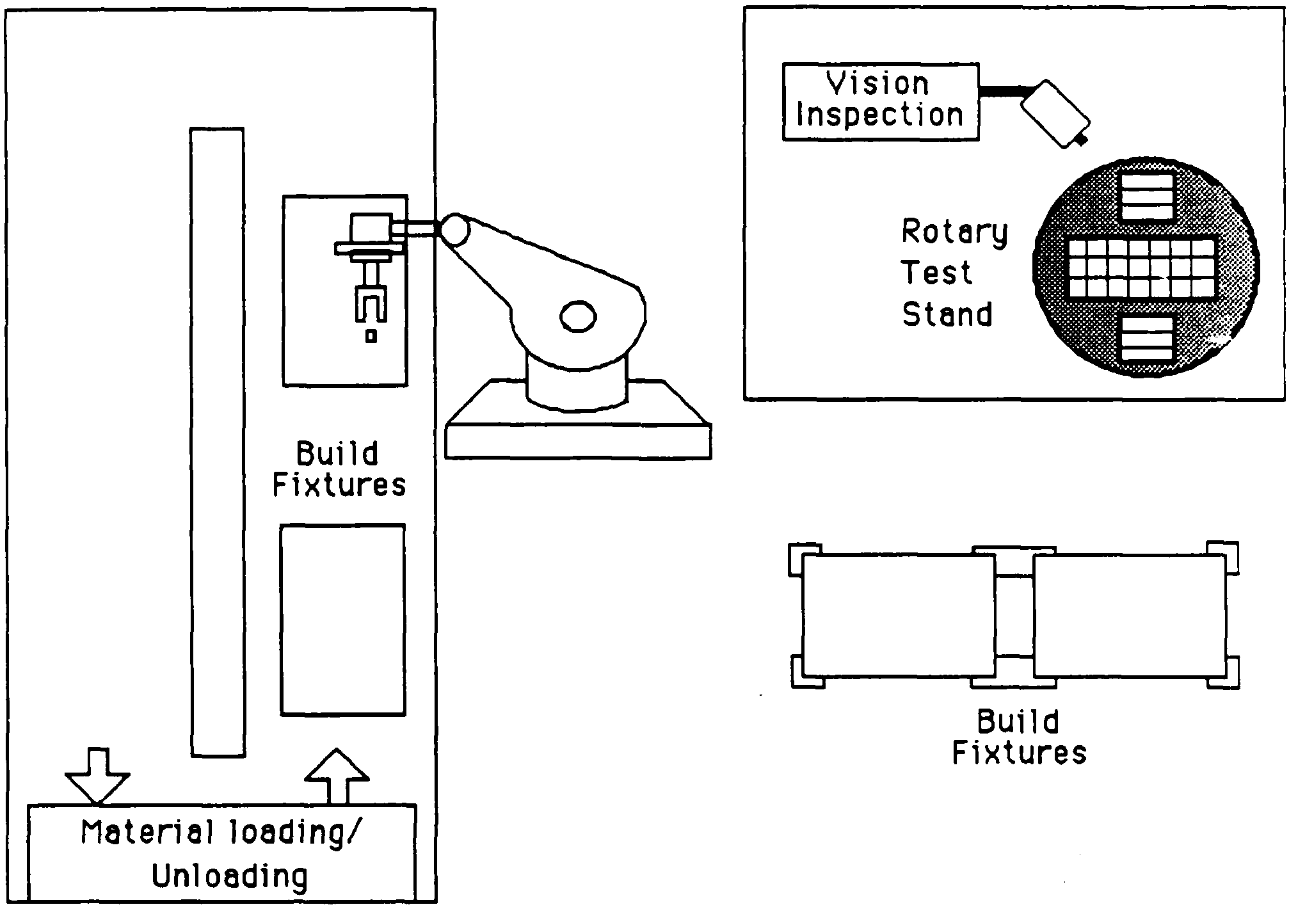
Workstation

Workstations are responsible for controlling the execution of one or more linked processes. The workstation initiates commands for specific actions to the appropriate process. In addition, the workstation monitors process activities through command acknowledgements and exception alerts.

Process

Processes are specific steps executed within an operation. At this low level, process controls provide acknowledgement of each command received and report each relevant action taken. As with workstations, the process control level reports exception conditions with respect to specific machine operations.

A conceptual overview of the workstation and process responsibilities is shown in Figure 3.2.1-2.



Workstation: Responsible for controlling execution of one or more linked processes
Directs commands for specific action to appropriate processes
Monitors process activity through command acknowledgements and exception alerts
Acknowledges work cell commands

Process: Responsible for executing specific steps within an operation
Provides acknowledgement of each command received and reports each relavent action taken
Reports exception conditions with respect to machine operation

Figure 3.2.1-2 Workstation/Process

3.2.2 Production Characteristics

Production characteristics describe the type of production operations that are employed for a particular set of products and are dependent upon a variety of factors including build schedule, lot sizes, product characteristics, and many other factors. The primary division of production characteristics is between functionally oriented (or process oriented) manufacturing and product oriented manufacturing. Additionally, characteristics of production may define the need for a mix between a functional and product orientation.

The assignment of production characteristics need not be global for an organization but should be determined when applied to each of the hierarchical levels within the factory. The following paragraphs briefly summarize the major distinctions between process and product manufacturing orientations and what the determining factors are in applying these characteristics at each manufacturing level.

Product Oriented Manufacturing

Product oriented manufacturing is characterized by grouping all functions common to an individual product in a close proximity or physical area. This means that each work area is strictly dedicated to the manufacture of individual products. In this regard, a major requirement of product oriented manufacturing is that there be sufficient capital equipment allocated to support each individual product line.

Process controls are characterized as those required specifically on a product by product basis, however production control is simplified by the single product focus. Inspection, under production oriented manufacturing, is again product oriented and is facilitated by a step-by-step process that follows the product through the production cycle. Training materials and aids must also be developed on a per product basis for each operation performed.

Material control is dedicated to each product and requires multi-point material distribution control for allocation of parts.

Functional (Process) Oriented Manufacturing

In contrast to product oriented manufacturing, a functional orientation groups processes common to all products in a physical area. This can provide an advantage for products requiring that a high degree of repetitive tasks be performed for the manufacture of the product. In that regard, while operators do not require shifting from processes, a level of sameness in the work can decrease productivity.

One of the major benefits of functionally oriented manufacturing is that production resources (such as capital equipment) is centralized and requires less duplication. As part of this benefit, product flow is forced through a common location, allowing for more control and tracking of production processes. This concentration on the process allows development of universal process controls and the development of more generic work aids and training.

Material handling and control becomes more concentrated under this scenario as limited classes of material are established for each single point of use or work area. In contrast, production control must be more spread out to monitor more production points for an individual product.

Combined Functional/Product Orientation

The combined functional/product manufacturing orientation represents the most common organization of characteristics in most manufacturing environments. This mix allows processes that are common to all products to be grouped in separate, distinct physical areas. In turn, processes that are unique to a specific product can be isolated in a separate physical area for more efficient production control.

The functional/product mix provides defined integration points for product/process routing splits and merges. Material handling is optimized by the ability to define specific material class requirements for each of the work areas. In addition, resource utilization is optimized due to the fact that resource orientation is defined for the most productive work flow.

3.2.3 Definition of ITM Project 87 Objectives

ITM Project 87 has a defined objective to increase the efficiency of the transformer and chassis areas by the use of modern assembly and test equipment. ITM Project 87 addresses the modernization of the processes and equipment used in the chassis and transformer assembly and test areas within the FM&TS department. This modernization will consist of an upgrading of manual assembly processes and methods, enhancements of test equipment and fixtures, automatic data recording, and the addition of automatic wire preparation.

The primary concentration of efforts for performing ITM Project 87 are focused on the work cell and workstation levels and improving the processes and organization of these levels.

3.2.4 Definition of Variables and Criteria

The variables and criteria for Project 87 are used to define more discretely the areas that most benefit from production and process improvements. The variables represent the major aspects of production operations while the criteria define the ways in which improvements can be measured.

Manufacturing operations variables are those areas within a manufacturing operation that are changed or affected by changes within the operations to optimize production. These variables are defined by three major categories:

- Production
- Material
- Information

Production Variables

Structure. The structure of production can be defined either in respect to the hierarchical levels defined earlier or as a specific operation's organizational structure. Organizational structures can greatly affect the flow of production, especially in the structure's responsiveness to the manufacturing flow problems and in its facility to implement modifications and changes to the manufacturing processes.

Layout. There are a number of ways a production area can be physically organized on the shop floor and this physical layout can greatly affect the manufacturing production flow. While this area is described in greater detail in the following section, it should be noted that there are a number of ways that a manufacturing area can be laid out but the specific layout depends upon the goals for the area and the criteria defined for that area.

Process Flow. In conjunction with layout, process flow can be optimized to group resources in a specific area and to consolidate material handling efforts. The definition of an optimized process flow is a major factor in defining an optimum physical layout.

Group Technology. Group technology addresses two major operational philosophies, one concerned more with the cellular organization of processes and work areas, and the other focusing on specific products and product families. These concepts are explored in detail in Section 3.3.

Material Variables

Material Management. The effective control and management of materials is key to efficient and profitable manufacturing. Material management encompasses scheduling materials (both raw materials and work-in-process) as well as being able to monitor material usage and production completions.

Material Handling. Material Handling ranges from totally manual to fully automated and the selection of the appropriate material handling methods depends upon the definition of the appropriate criteria such as product characteristics and movement distances required.

Information Variables

Systems. Information systems can, like material handling methods, range from totally manual to fully automated. All manufacturing processes at any level include production information systems and it is important to define systems that are responsive to the manufacture of a product and that aid in that production rather than affect it adversely.

Control Networks. These networks, either formal or informal, serve to monitor and control production processes more accurately, thereby allowing other operations to be targeted for improvements. With the advent of computer controlled networks, much of the lower level control functions can now be readily automated dependent upon the specific criteria for a process.

Production Criteria

Production criteria are necessary for the development of any facility/operations improvement program. These criteria cover a wide range and an all inclusive list would be far too long for consideration in any project. The following paragraphs describe some of the major production criteria that have been used in the development of improvements for the FM & TS ITM Project 87.

Capital Investment (Duplication of Equipment)

Capital equipment should be considered for duplication when product volume processed requires time in excess of 96 hours/week (greater than 2 shifts per 24 hours) or unit is critical to production such that down time in excess of one shift would seriously impact production.

Square Footage Required (Process vs. Product)

Consideration must be made for flow lines and/or product queues. If the area occupied by single product-related process exceeds 50% of space utilized, the process should be incorporated into product flow. This allows processes to function at peak efficiency and product specific operations to be performed in an optimum area.

Process Time for Separate Operations

If process time at a remote location (including movement) exceeds one shift, it should be incorporated into the product flow. Alternatively, a facility relayout may be considered to bring separate operations together. (Obviously, the cost effectiveness of process incorporation or facility relayout is governed by product volume, available capital, and facility costs.)

Product Profile

The following factors dictate product oriented assembly (versus process oriented) to avoid quality/damage problems:

- *Product Size*. Weight or volume of product precludes movement to a remote processing point without risk of damage.
- *Process Complexity*. Process employed has an intricate or extensive set of steps necessary to accomplish particular task making it inconvenient or subject to error if intermixed with other processes.
- *Parts Count*. Unit has high number of unique parts which, by organizing in a single product workstation, ensure higher quality and throughput when contrasted with a multi-product workstation.
- *Special Handling Requirements*. Unit configuration or delicate nature dictates minimizing handling or transport during intermediate assembly steps.

Material Transport Related Factors

If time taken for

- Material Movement (distance)
- Queueing time (Wait States)

exceeds 20% of actual processing time, an operation should be considered for product line orientation.

Personnel (Skill Level, Training, Productivity)

Ability to specialize in one product-related process area should be weighed against impact on quality/training of combining similar operations to concentrate equipment or processes.

Equipment Utilization

Process should utilize equipment to the extent that simple payback can be achieved in 1 to 2 years. Actual operational time may dictate decision to implement shared usage if significantly below 50%.

Ease of Implementation

Includes training and development of assembly, test aids, and software.

Level of Support Services Required [Heating, Ventilation, Air Conditioning (HVAC)]

Cost factor for consideration when expanding or relocating uses additional support services.

Product/Process Flow Optimization

Factors which impact idealized (or linear) area flows must be defined. Acceptable percentage deviation must be established between idealized and actual by modeling product and process arrangements.

Ease of Expansion/Capacity

Initial investment factor should allow a minimum of 20-50% increase in flow (single shift). Expandability should be evaluated on payback of process time efficiencies similar to justification for base unit (1 to 2 years).

Throughput

Optimized combination of operations minimizing set-up and tear-down times so that equipment utilization is maximized for productive output.

Equipment Limitations

Factored in terms of:

- Percentage of area occupied
- Percent of total utilities consumed
- Percent of increase in labor expense

to overcome capacity limitations.

Changeover Capability (product-to-process and vice versa)

Key factor employed in major factory realignments. Normally encountered in multi-step equipment employing universal tooling or fixtures.

Viability

Must have rational basis for justification in terms of real savings in:

- People
- Materials
- Time

Batch vs. Unit Build

Primary factor is impact of set-up and typical duration of key elements like diagnostic time, tool change-out, etc.

Number of Products/Options Manufactured

Line orientation will optimize mix of products and calculated percentage of options (either projected or historic).

Volume Impact

Quantities exceeding 25% of total work at an operation should be considered for separate area based on accumulated weight of other factors. Above one-third, volume should be the determining factor.

Trade Off Analysis

The criteria described above must be valued as it applies to each of the specific production variables. This requires selecting the most significant criteria (as shown in Figure 3.2.4-1) and developing a means of quantifying its effect on the production variables.

Once the variables and their effect on production have been defined and criteria for each of these variables has been weighted for relative importance, it is possible to develop a logical model that will aid in the cost trade off decision making process.

3.3 Work Area Design

In developing improved work area designs, the specific methodology employed utilizes a great deal of production and product specific data to aid in the development of an optimum work area. General systematic layout planning methods were used in conjunction with methods developed specifically for ITM Project 87. The specific methods employed for ITM Project 87 are described in Figure 3.3-1. In general, these can be characterized in four phases:

1) Location
2) General overall layout
3) Detailed layout planning
4) Installation

In addition to these four phases, five major considerations are used for systematic layout planning. Mnemonically, these are referred to by the letters PQRST. These are defined as:

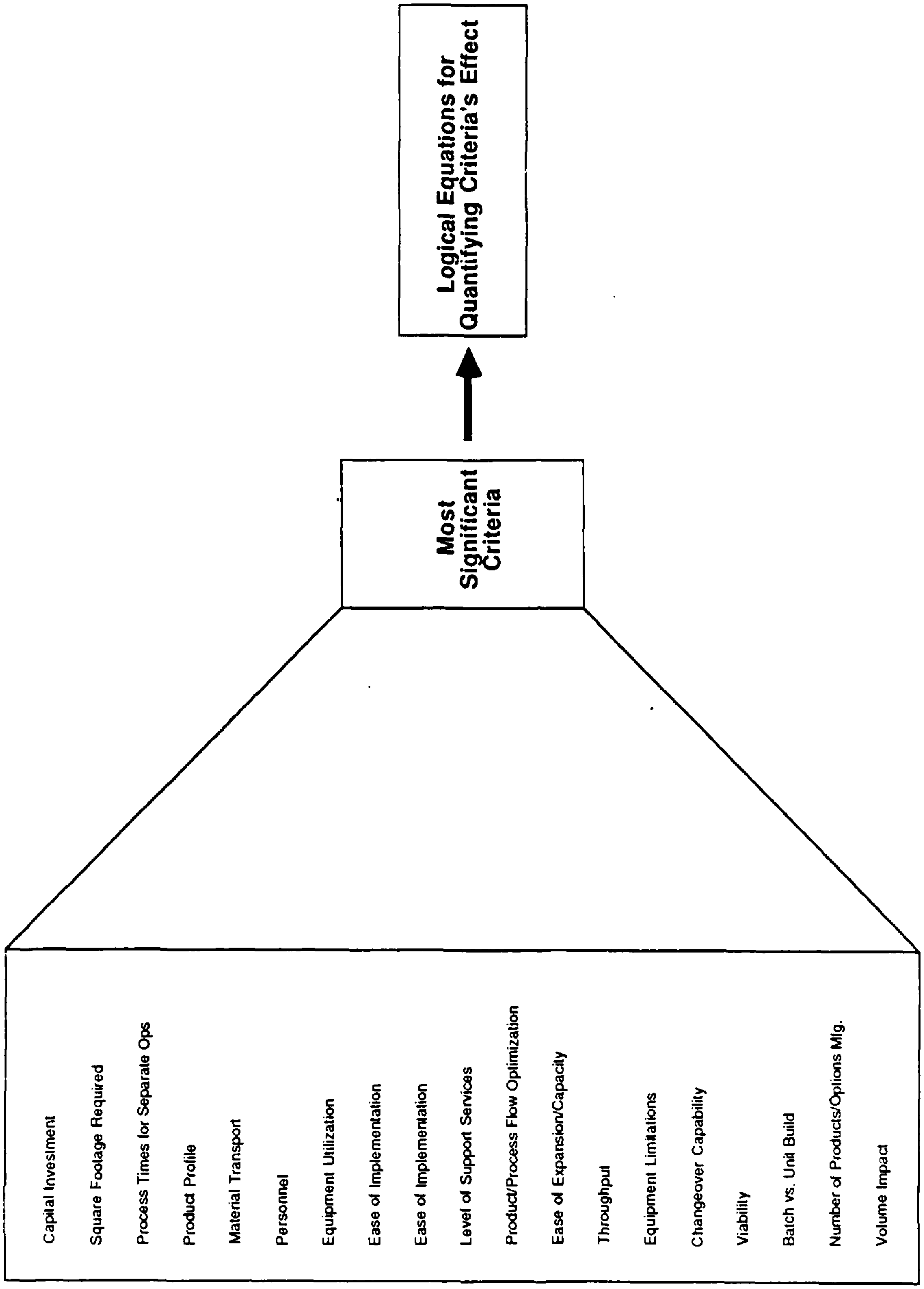


Figure 3.2.4-1 Valuation of Criteria

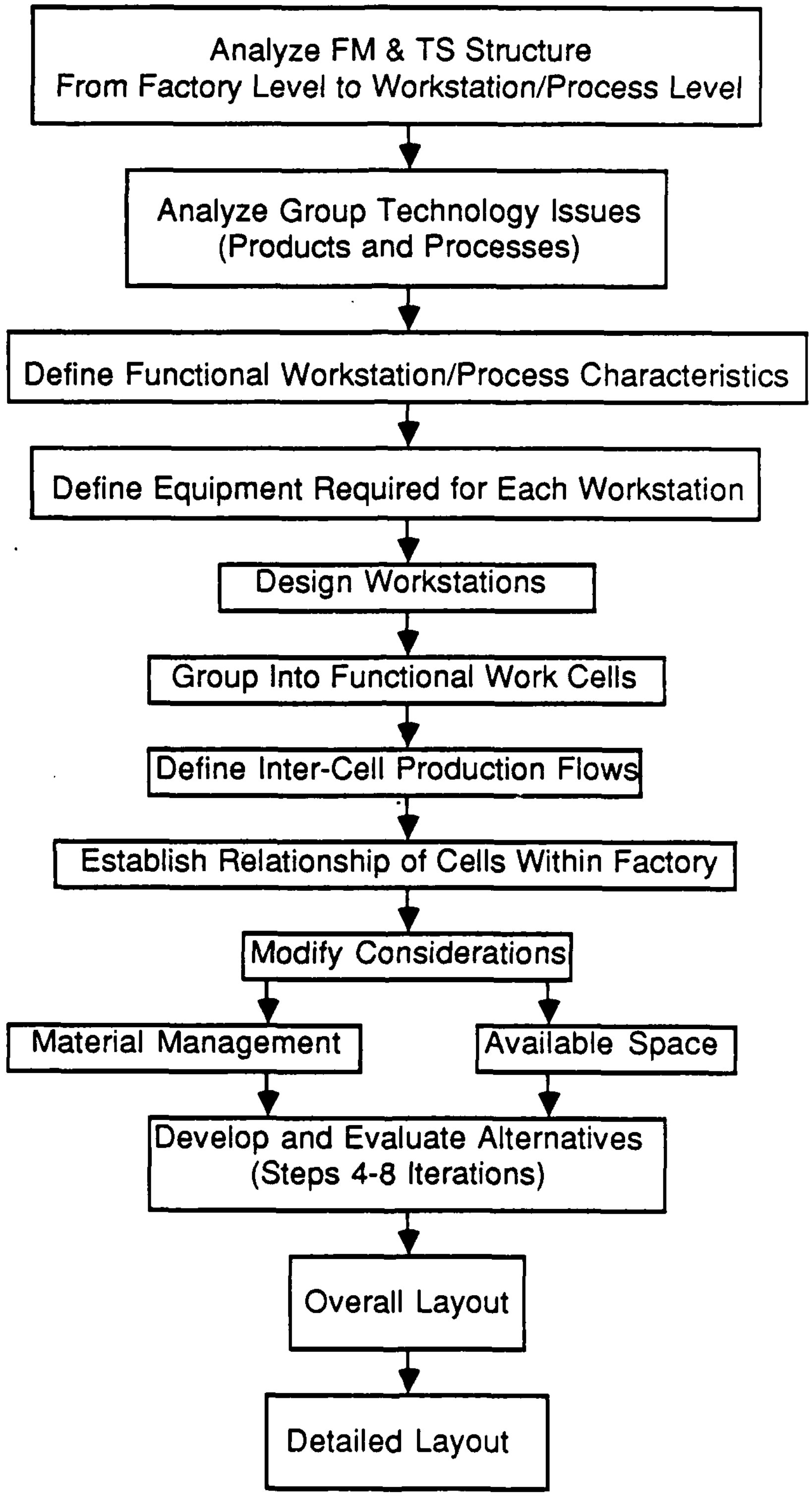


Figure 3.3-1 Methodology Flow Diagram

P= Product plus variations and characteristics
Q= Quantity or volume
R= Routing or process (this involves both sequence and machinery utilized)
S= Services and support
T= Timing of PQRS (when, how long, how soon, how often)

These primary considerations are employed in all phases of the work area design.

As shown in Figure 3.3-2, three primary sets of data (Production Layouts, Production Flow Studies, and Process Matrices) are used to define each work area's specific requirements along with providing some of the raw data used to analyze the applicability of Group Technology. These factors are then used to develop workstation requirement profiles which in turn lead to the development of workstation designs. The final workstations are then grouped (either functionally or by product) to develop optimized work cells.

The different variables and criteria are employed during this process at the workstation and work cell level to ensure that the designs meet the overall requirements set forth by ITM Project 87. The following section provides an overview of the components employed by this methodology and how the results are developed.

A production flow study was performed by Honeywell's Tech Mod Industrial Engineering Group to document the locations where the operations called out on the production layout are actually performed in the "As-Is" operations. This provides input into determining the groupings of operations at specific workstations and work cells.

Production layouts represent some of the most important input of data to the design of work areas. Production layouts not only provide routings of the various products produced but several other important pieces of information. These include:

- Operations callout numbers and descriptions. These provide a shorthand method for analyzing how the operations fit within the routings.

- Production process details. These provide specific process details for the more complex operations called out by the layout summary. Included are references to commonly used processes detailed in supporting documents. This is key to defining the operations performed at a specific workstation.

- Operation standard hours. These provide a relative method of measuring the time required to perform the called out operations.

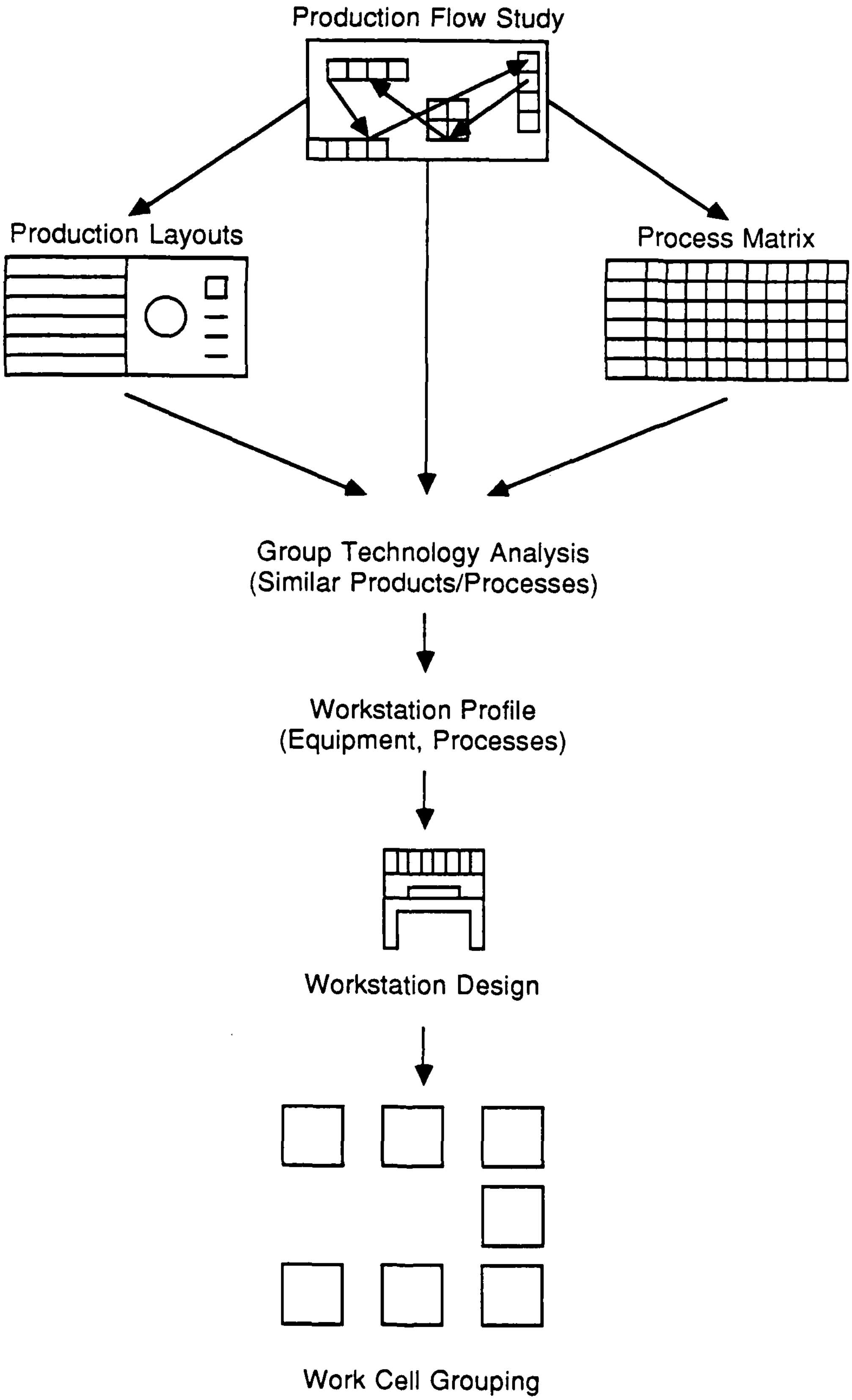


Figure 3.3-2 Work Area Design Methodology

- Fasteners/common hardware. Descriptions of all fasteners and other miscellaneous hardware used in the production process were analyzed using group technology techniques described in Section 7.0.

- Parts and materials. Required subassemblies, parts, and materials (paint, ink, wire, coatings, etc.) are listed in the layout at the specific step where required.

A process matrix was then developed to determine the hours required annually for each operation. The following methodology was employed to develop the process matrix:

1) Production layouts provide initial data for establishing standard hours per operation per part number. Data was correlated with operation descriptions along x axis, part number along y axis, and standard hours entered in matrix grid.

2) Production totals (box counts) were entered for years 1986 and 1987 on separate matrices. These were then multiplied for each part number and each new operation column was totaled (total hours per discrete operation) per program.

3) Production layouts were referred to subsequently for grouping operations that were (or could be) performed at a specific type of workstation. These were reviewed by the appropriate production personnel for accuracy. The matrix was then consolidated into major categories for both 1986 and 1987 production. This was then verified for 1986 using the Foreman's Cost Report (for total hours in operational area).

4) Business volume projections were established for the operational area and standard hours were projected for ten years using an established percentage growth for the FM & TS operations derived from FSO marketing projections.

5) Actual hours for each type of workstation were established using a cost variance ratio established by the FM & TS cost accounting department.

6) Actual number of workstations was established by dividing actual hours per type of workstation by 1800 hours. The assumption of 1800 hours/year/employee allows for 80 hours vacation, 80 hours holiday, and 120 hours for lost time (sick, jury, etc.) from the gross 2080 hours (52 weeks x 40 hours per wk.) available each year.

Each operational area was analyzed utilizing this type of matrix to accurately determine the number of workstations and as input in developing their location within the overall area.

The workstation profiles defined during the development of the operations matrix were then analyzed for processes performed at each type of workstation. These processes and the types of fasteners, etc. used (developed in the Group Technology matrix in Section 7) then determined the equipment requirements for each workstation. A generic workstation is then defined which can meet the overall requirements of all of the possible stations for the work area. The specific equipment requirements for each station and the generic workstation design is then employed to define the configuration of each of the specific workstations for the work area.

Once all of the workstations have been designed, the grouping of the stations is laid out based upon the process flow to provide optimized routings for the majority (approximately 80%) of the product that will be built in the work area. In addition, the accessibility of resources is analyzed in relation to the work cell designs as well as the physical characteristics of the products assembled. Examples of cellular groupings are shown in Figure 3.3-3.

After the work cells have been developed, they are laid out for optimum routing between the cells. Once the work area has been designed the material handling and storage requirements are developed to facilitate the process flow between cells.

3.4 Equipment Selection Approach

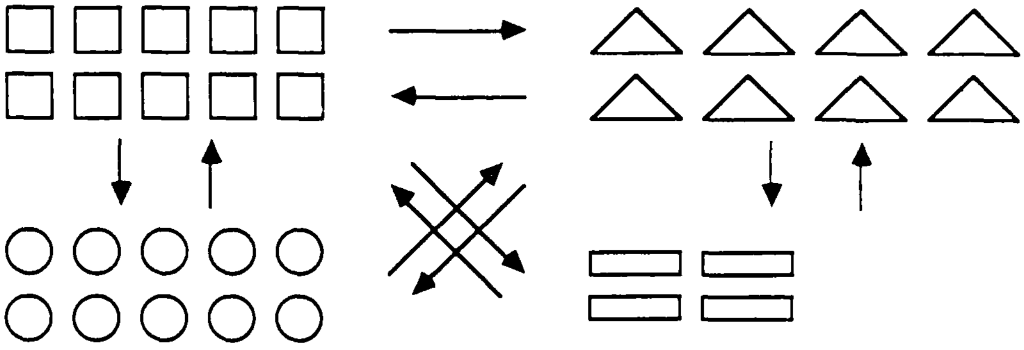
The selection of equipment employed for ITM Project 87 was defined using a general approach and then a more refined methodology based on this approach was used for each specific piece of equipment. This general approach is described below and presented pictorially in Figure 3.4-1.

The first step in the selection of equipment is to define all of the possible equipment required to perform the process necessary for production. This was approached from several different vantage points:

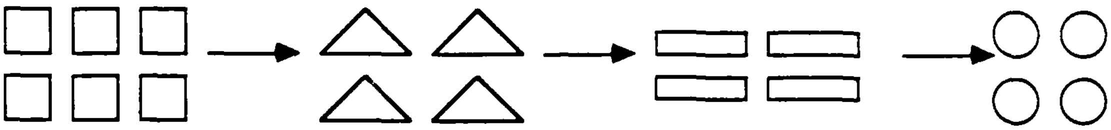
- Current equipment survey. All equipment currently used in a production area was reviewed for functionality, age, ease of repair and availability of spares, as well as several other factors specific to the unique piece of equipment.

- Production processes. The processes called out by the production layouts were reviewed to determine if current equipment could adequately perform those processes and what new available equipment could be used to perform production processes.

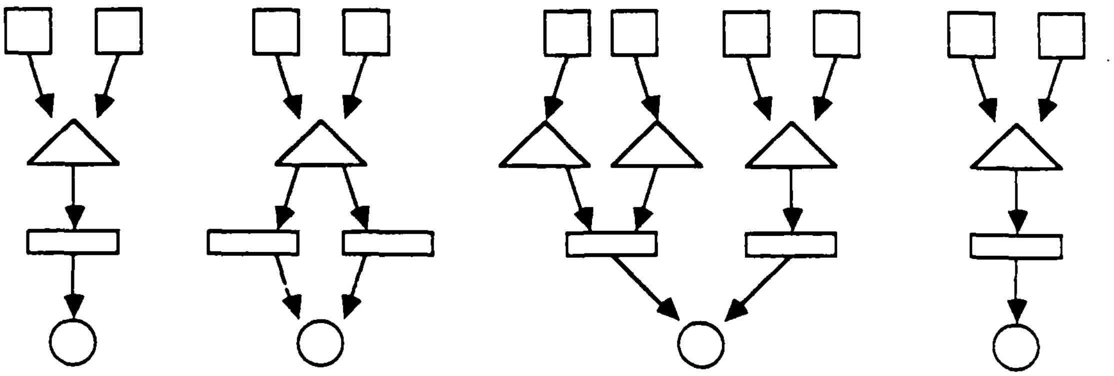
- Technology overview. Recent technological advances in production equipment were reviewed to ensure that during the equipment evaluation process all applicable or substitutable technologies were understood in relation to the production area and the processes performed there.



Clustered, jumbled:
- Clusters of generic workstations
- No attempt to organize by product flows
- No easily identifiable flow path or, organization contrary to flow path



Clustered, flow line:
- Clusters of generic workstations
- Organization by product flow



Cellular:
- Unlike workstations grouped into cell to produce a product family
- Only one wrokstation of a type, except where more needed for balance
- Cell-to-cell organization by product flow

Figure 3.3-3 Work Area (Cell/Station) Organization

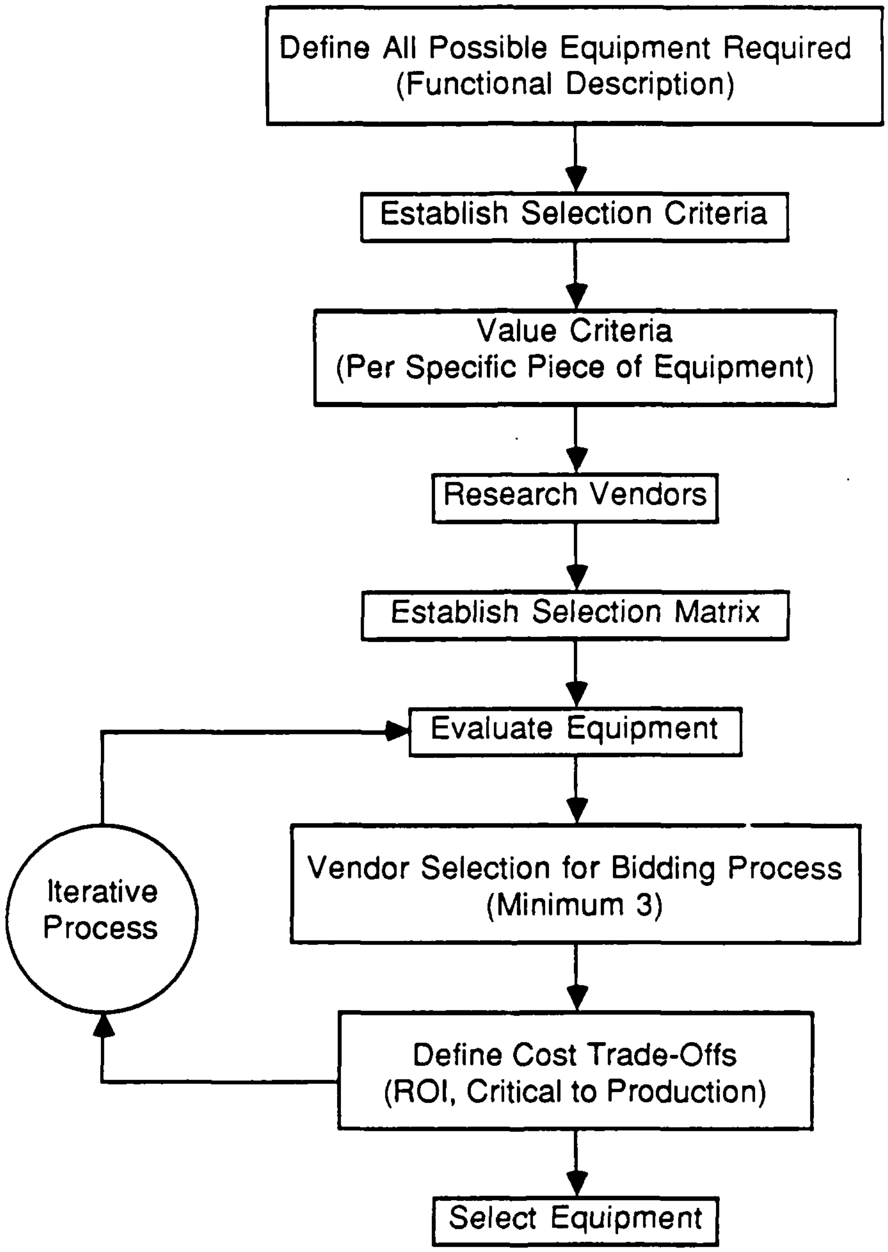


Figure 3.4-1 Equipment Selection Approach

Following the establishment of production equipment requirements, selection criteria were established to evaluate each individual piece of equipment. A general overview of these criteria includes:

Physical Criteria

Conformance to Requirements - Equipment meets (or exceeds) capabilities required, such as capacity, frequency, accuracy, MTBF.

Ease of Use - Required level of technical expertise/training necessary to effectively operate equipment.

Technology Level - Employment of state-of-the-art features or innovative application of technology that enables user to more effectively perform intended task.

Multiple Users - Ability to support more than one user simultaneously (either operating or programming).

Network Capability - Ability of equipment to be networked to other similar units or to centralized data files or controller.

Defect Detection and Reporting Capabilities - Effectiveness of reporting of defects on unit under test so as to permit repair in shortest possible time.

Support

Serviceability - Ease of maintaining equipment plus vendor support capabilities/response level.

Technical Support Requirements - Level of technical expertise/training required to effectively support (program, maintain, etc.) equipment.

Cost of Programming - Relative effort required to develop operational programs for equipment.

Physical Characteristics

Portability/Moveability - Effect on critical adjustments/required participation of vendor.

Ease of Installation - Effects on installation due to physical size, mounting/isolation requirements, vendor or customer team required.

Ease of Upgrading/Modifications - Convenience of installing additional capabilities/features/options as well as field changes (both hardware and software).

Physical Interfacing - Relative level of ease in providing interface to unit under test (UUT) or other equipment being operated on.

Cooling Requirements - Special HVAC requirements necessary for equipment due to operating temperature and range.

Environmental Impact - Provisions required due to equipment-generated heat, noise, vibration, etc.

Power Requirements - Exceptional or unusual power requirements for the equipment as compared to similar types of equipment being considered.

Special Environmental Requirements - Special environment requirements such as "clean" room, dark room, isolation mounting, etc.

Vendor Evaluation

Delivery - Availability of equipment in accordance to needs.

Vendor Reliability - Supplier's record in delivering and supporting equipment (evaluate by questioning other users).

Equipment Cost - Evaluated in relation to other similar pieces of equipment under evaluation for a given use (i.e., relative cost of unit).

It is then necessary (for each piece of equipment required) to "weigh" or value the criteria, selecting the most important criteria for a specific piece of equipment. The weighted factors associated with that equipment are then used to perform an initial vendor review.

The weighted criteria is ranked for level of importance or applicability to the decision making process and listed on one side of an equipment selection matrix (shown in Figure 3.4-2). This matrix is used to evaluate the vendor's product's applicability and to screen out the vendor's whose equipment is not suitably matched to the requirements.

The vendors whose products meet the initial requirements are sent specifications (RFQ's) to respond to. Once the initial cost of the equipment is established, the selection process then becomes an iterative process of defining the cost trade-offs involved, determining if the ROI is sufficient and reviewing the criticality of the new equipment and its effect on production. The final step in this process is the purchase of the equipment and the initiation of the program's implementation.

Equipment Selection Criteria	Vendor A	Vendor B	Vendor N
Conformance to Requirements			
Ease of Use			
Technology Level			
Multiple Users			
Network Capability			
Defect Detection and Reporting Capabilities			
Serviceability			
Technical Support Requirements			
Cost of Programming			
Portability/ Movability			

Figure 3.4-2 Tooling and Equipment Evaluation Matrix

Equipment Selection Criteria	Vendor A	Vendor B	Vendor N
Ease of Installation			
Ease of Upgrading/ Modifications			
Physical Interfacing			
Cooling Requirements			
Environmental Impact			
Power Requirements (Normal vs. Exceptional)			
Special Environmental Requirements			
Delivery			
Vendor Reliability			
Equipment Cost			

Figure 3.4-2 Tooling and Equipment Evaluation Matrix (cont.)

SECTION 4

"AS-IS" PROCESS

The following section presents a description of the "As-Is" condition of the FM & TS operations. This includes a brief description of the type of product currently in production, the operations structure, the organizational structure as well as the personnel involved in FM & TS Production. In addition, the floor plans of the FM & TS Chassis and Transformer Areas are included as well as the process flows for typical products. Also included is a characterization of the material flow and information flow as well as a description of the equipment currently used and an evaluation of its suitability.

An overview of the current "As-Is" process required to produce FM & TS products is depicted in Figure 4.0-1.

4.1 FM & TS Production Overview

FM & TS Production manufactures flight control products for major programs as well as producing spares for these programs.

4.2 FM & TS Program Profiles

Flight Management and Targeting Systems Production assembles and tests high technology military flight control and targeting systems built under specific customer contracts. Therefore, while there may be several products within a particular program, each program must be managed and controlled to comply with a specific customer's requirements. The systems that are built under each of the program's currently under contract to FM & TS are typically made up of a variety of components, including:

- Computers
- Control Panels
- Sensors
- Control Sticks
- Electronics Units

The orders for any one of the program's products may be made for complete systems, modification packages, or spares.

In addition to the various programs, a significant amount of FM & TS Production's business is made up of military spares as well as transformers for use in FM & TS and other areas in Honeywell's Military Avionics Division.

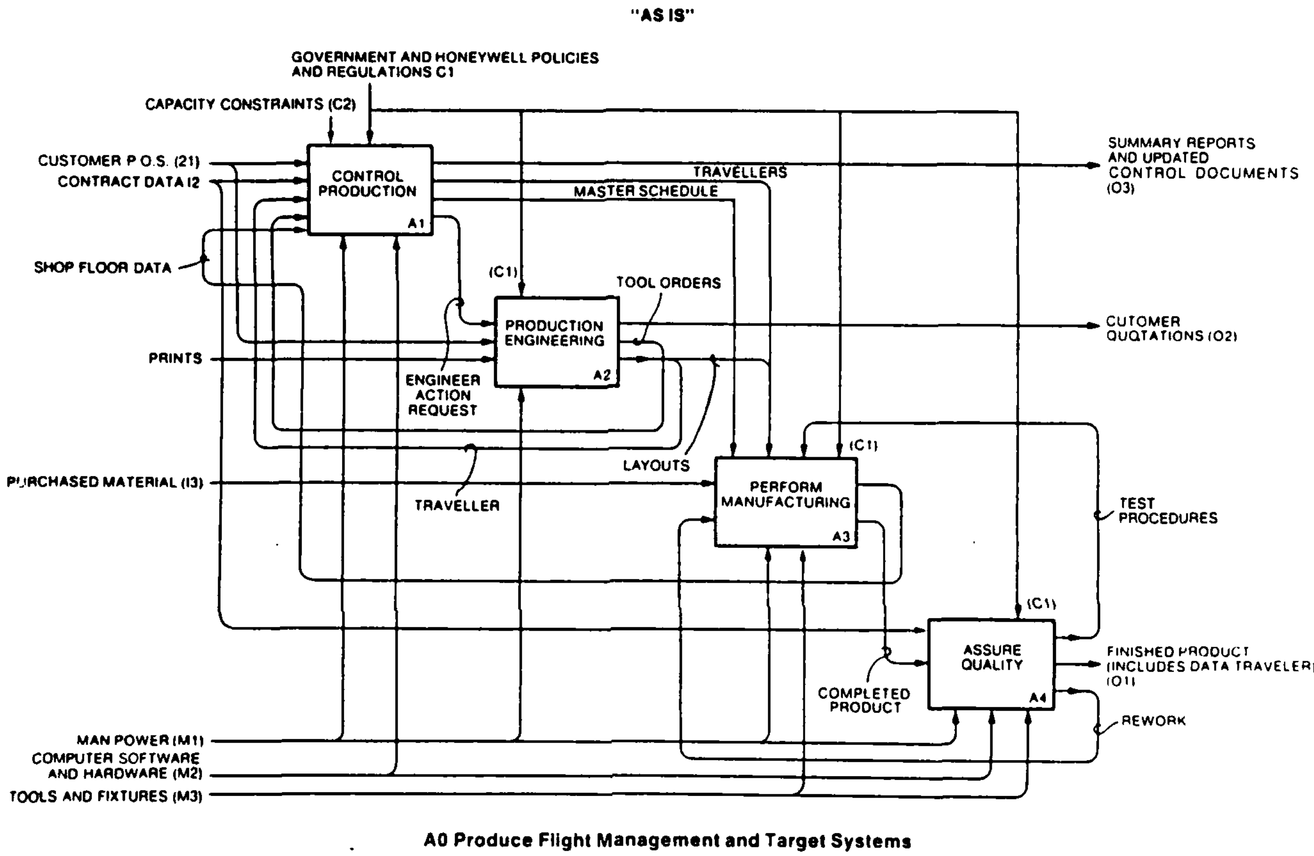


Figure 4.0-1 "As-Is" Production Process (FM&TS)

4.3 FM & TS Operations Structure

The following section describes the structure of FM & TS Production operations and the characteristics of the two areas primarily addressed by ITM Project 87.

The FM & TS Production operations structure is most appropriately described in terms of product orientation or process orientation or a mix of both at each of the hierarchical manufacturing levels described in Section 3. Briefly, the differences between product and process oriented manufacturing can be characterized as follows.

Product Oriented Work Areas:

- Allows all functions related to a product to be contained in a single organization
- Requires all equipment necessary to support a product to be controlled by that product group
- Provides all necessary support functions (e.g., material handling, production planning, QA, etc.) internally
- Concentrates all activities related to product operations within close physical proximity, thereby reducing material movement
- Requires dedicated personnel to perform operational (assembly/test) tasks
- Theoretically allows compact layout but this is dependent upon the size and nature of process equipment and the product handled
- Minimizes material queuing by layout constraints
- Dedicates material handling to a product

Functional (Process) Oriented Work Area

- Concentrates assembly machinery and test equipment for shared usage (maximum utilization)
- Allows concentration of specific skills and development of technology centers
- Increases need for material movement from function to function
- Requires coordinated work planning function between process centers

- Support activities generally are provided by outside "centralized" organizations

- Layout/space utilization is generally efficient from a process/material flow perspective. Requires additional "aisle" space.

- Material queues must allow for increased transits to using areas and combined throughput rates

The definition of these two orientations provide a basis from which to analyze the "As-Is" structure of the FM & TS operations. The hierarchical levels referred to in this section are more completely described in Section 3 and can be briefly summarized as:

- Factory (which is represented as the overall FM & TS Production operations)
- Work Center
- Work Cell
- Workstation/Process

Work Centers

At the work center level (as shown in Figure 4.3-1), the division between work centers reflects both a product and process mix. The primary emphasis is on process for all of the major mature programs currently under contract and on a product orientation for all of the new or variable programs. The two work centers that are of concern for ITM Project 87 are the transformer work center and the chassis work center.

The transformer work center is, in essence, a product oriented work center. It does not function strictly as a supplier of transformers to FM & TS but also produces products for several other divisions within Honeywell. The transformer work center is also responsible for the development of prototype transformers that, when incorporated into high volume products, are off-loaded to an outside vendor. In this regard, the transformer work center can be considered a low volume, high quality producer of transformers to support both FM & TS and other divisions internal to Honeywell's MAvD.

The major characteristics of the transformer work center is the grouping of all product related functions, necessary equipment and personnel, and support functions in a single organization. While it is logical that this work center should be located in a geographically central area, this is not the case in the "As-Is" condition.

The chassis work center is, on the other hand, a process oriented work center. The chassis work center is dedicated to the production of chassis and wire wrap plates for the flight management and targeting systems produced by Honeywell. While this is a low volume, high quality work center, it supports

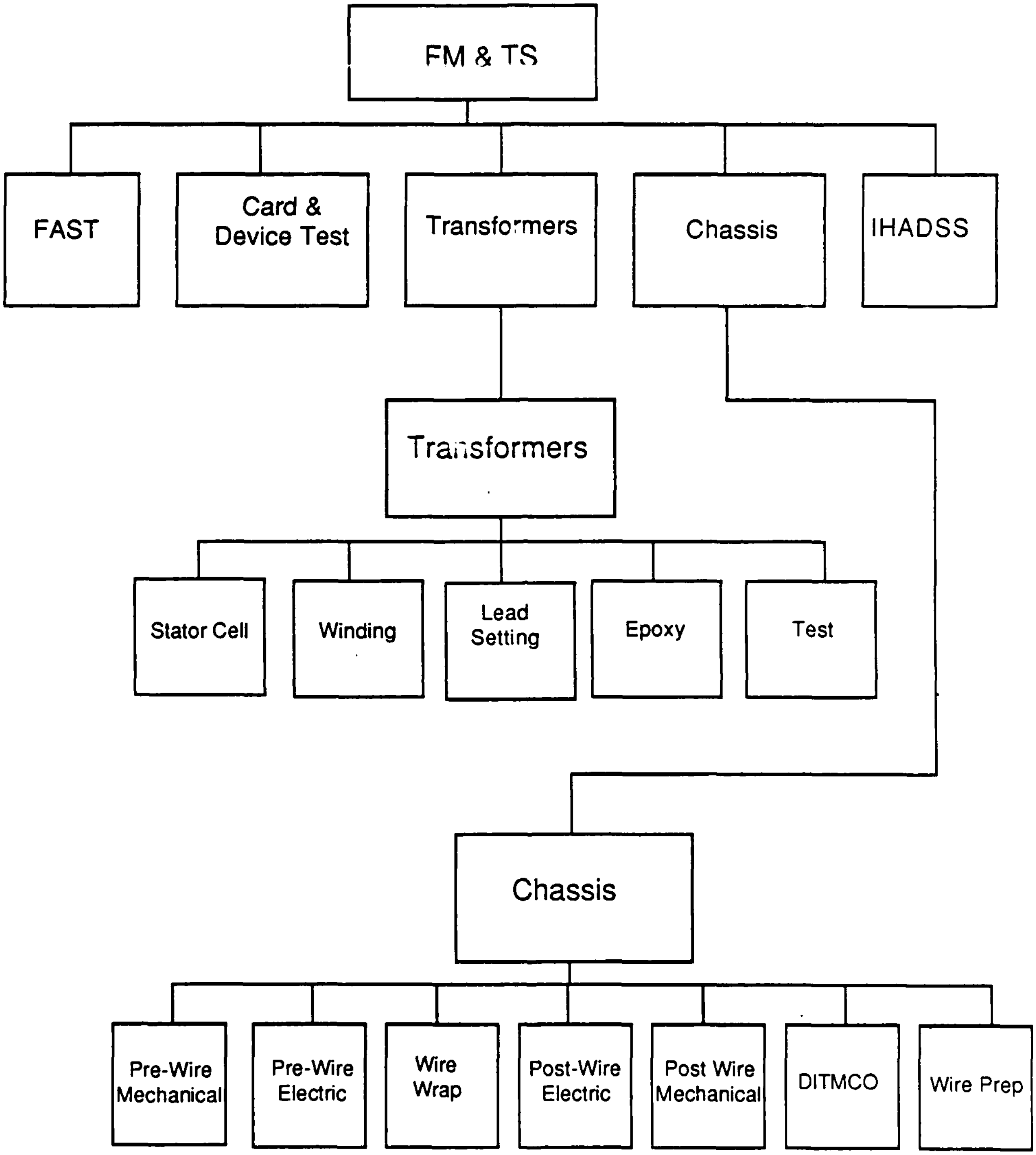


Figure 4.3-1 FM&TS Work Center Structures

virtually all of the programs within FM & TS and functions as a stand-alone process center.

The structure of the chassis area work center allows for a concentration of skills and the development of technology centers. Other functions are more centralized and good coordination is exhibited in controlling the work of this process center with other dependent centers.

Work Cells

The work cells within both the transformer and chassis work centers are primarily dedicated to processes. In the transformer work center, this is due to the fact that while this work center is product oriented, all of the items produced within it undergo very similar process steps that can be divided strictly by process. The only exception to this is the stators, which are wound and lead set in their own cell due to the specific nature of the processes required. These work cells are:

- Stator Cell
- Winding Cell
- Leadsetting Cell
- Epoxy Cell
- Test Cell

The work cells within the chassis work center are strictly dedicated to processes involved with the manufacture of chassis and wire wrap plates. These work cells are:

- Pre-Wire Mechanical
- Pre-Wire Electrical
- Wire Wrap
- Post-Wire Mechanical
- Post-Wire Electrical
- DITMCO
- Wire Prep

Most of the work cells that are contained within the chassis and transformer work centers can be characterized as combining all like functions in a designated location providing work space efficiency. These process cells also allow a greater focus on operator specialization as well as on process/quality evaluation of several different products.

Work Stations

The work stations in both the transformer and chassis area are primarily process oriented. This is typically characterized as one process per station but with the possibility of multiple products assembled at that station. Additionally, in the chassis area, some workstations are reserved for particular assemblies or models. While this multiple product orientation makes training somewhat more complex, the expertise of the operators allows for more flexible shifting of personnel.

4.4 FM & TS Organizational Structure

The Flight Management and Targeting Systems (FM & TS) Production operations play a central role in Honeywell's Military Avionics Division's (MAvD) Flight Systems Operations (FSO) organization. The organizational structure of FSO is divided into several major functional areas, including:

- Production
- Program(s) Management
- Engineering
- Product Assurance
- Procurement

The areas within FSO are structured as independent, function-oriented organizations that report to other areas on a "dotted line" basis. Within the Production area of FSO, the organizational structure is primarily high-level-product oriented. These high-level-product related areas are divided into:

- Flight Management and Targeting Systems Production
- Missile System Microwave Production
- Printed Wiring Assembly
- Aircraft System Microwave Production
- Advanced Systems
- Central Production Services

While the divisional distinctions within FSO are primarily high-level-product oriented, the products produced by each group are also significantly distinct from a manufacturing process perspective.

The Flight Management and Targeting Systems Production operations are functionally divided into several areas, including:

- Production Engineering
- Production Control
- Assembly

These areas, which are separated organizationally, are interrelated to work together in an overall manner to support each of the products manufactured by the FM & TS operation. In that respect, each of these divisions provide input and receive assistance from the other two areas.

While the organizational division at this level is functional, the inter-division communication is defined by specific product programs. While this requires comprehensive management by each of the supervisors, it allows for direct information exchange where it is most beneficial (i.e., for each of the FM & TS programs).

Section 4.3 presented the structure of operations within FM & TS Production and the preceding paragraphs have provided a general overview of the role of FM & TS within Honeywell's MAvD. The following sections describe in a more detailed form the personnel within FM & TS in general as well as specifically focusing on personnel within the chassis and transformer areas.

4.4.1 Personnel

Of the total number of personnel employed by FM & TS Production approximately half of these personnel are dedicated to support services while the other half are assigned directly to production activities.

Of the number of personnel dedicated to production in the transformer area approximately 89% are operators (in either winding, lead setting, etc.) and 11% are technicians.

In the chassis area 80% are operators and 20% are technicians.

4.4.2 Group Leaders

Group leaders are responsible for a wide variety of activities including issuing, ordering, and moving parts; assisting and training operators; maintaining production related data; and other miscellaneous activities. For the consideration of ITM Project 87 though, the use of Group Leaders does not directly impact the implementation of improved assembly and test equipment and processes with the exception of training requirements that are a result of the new equipment and processes.

4.4.3 Production Control

As with Group Leaders, the consideration of Production Control personnel as cost drivers for ITM Project 87 is not as quantifiable and does not directly impact the implementation of improved assembly and test equipment and processes.

4.5 FM & TS Area Layouts

The following sections describe the "As-Is" layouts of the overall Honeywell FM & TS Production as well as specific layouts of the chassis and transformer areas. Figure 4.5-1 depicts the location of the chassis and transformer areas within the overall St. Louis Park facility. One of the more important features that can be noted by this layout is the great distances between the different locations of work cells within the transformer work center (wind & test, epoxy room, and lead set).

In general, the area configurations are limited by irregular physical boundaries which inhibit the ability to design a straightforward work flow. Work "cells" or technology "clusters" are not able to be accomplished due to the work space limitations imposed by inefficient configurations and scattered storage modules.

4.5.1 Chassis Area Layout

The chassis area is shown in Figure 4.5.1-1. The functions within the chassis group can be divided by the following groupings although these groupings are not currently used to define specific "work cells". These groupings are:

- Pre-Wire Wrap
- Wire Wrap
- Post Wire Wrap

As described in Section 4.7, "Material Flow", operations for each of the "cells" can be performed at several different workstations which requires backtracking, dead-ends, and other impediments to production flow.

4.5.2 Transformer Area Layout

The Transformer area is shown in Figure 4.5.2-1. It is especially important to note that the operations performed by the transformer group are located in three geographically distinct areas. This requires the use of the stores group to move work across and down corridors and has a negative impact on production which is described in greater detail in Section 4.7.

4.6 FM & TS Production/Process Flow

Production flow is typically characterized by a combination of information flow, material flow, and process flow. For the purposes of this section, the concentration on production flow will be in regard to the specific area's process flow and subsequent sections will describe the material and information flows.

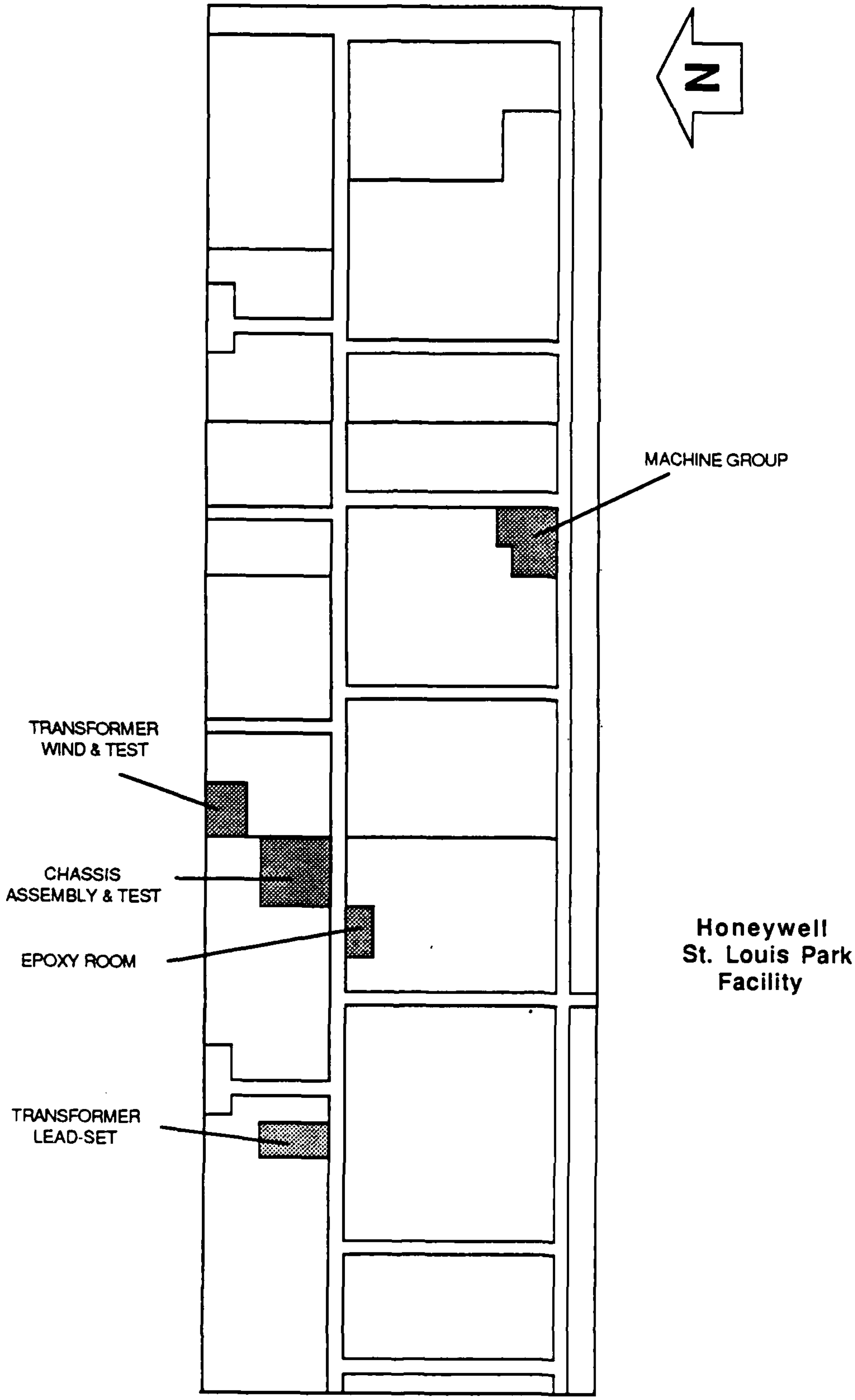


Figure 4.5-1 Chassis & Transformer Areas As-Is Location

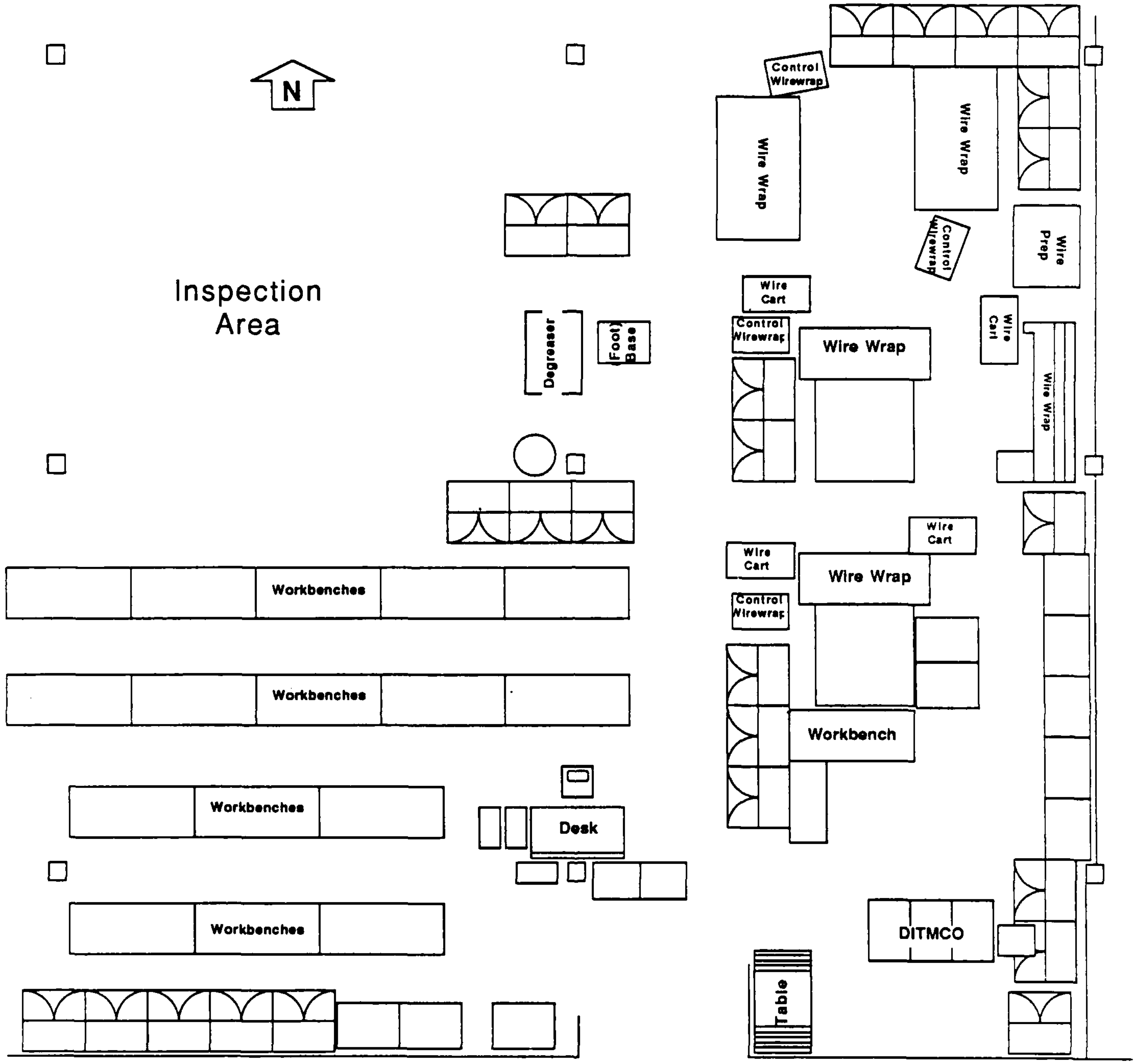


Figure 4.5.1-1 "As-Is" Chassis Assembly and Test Area

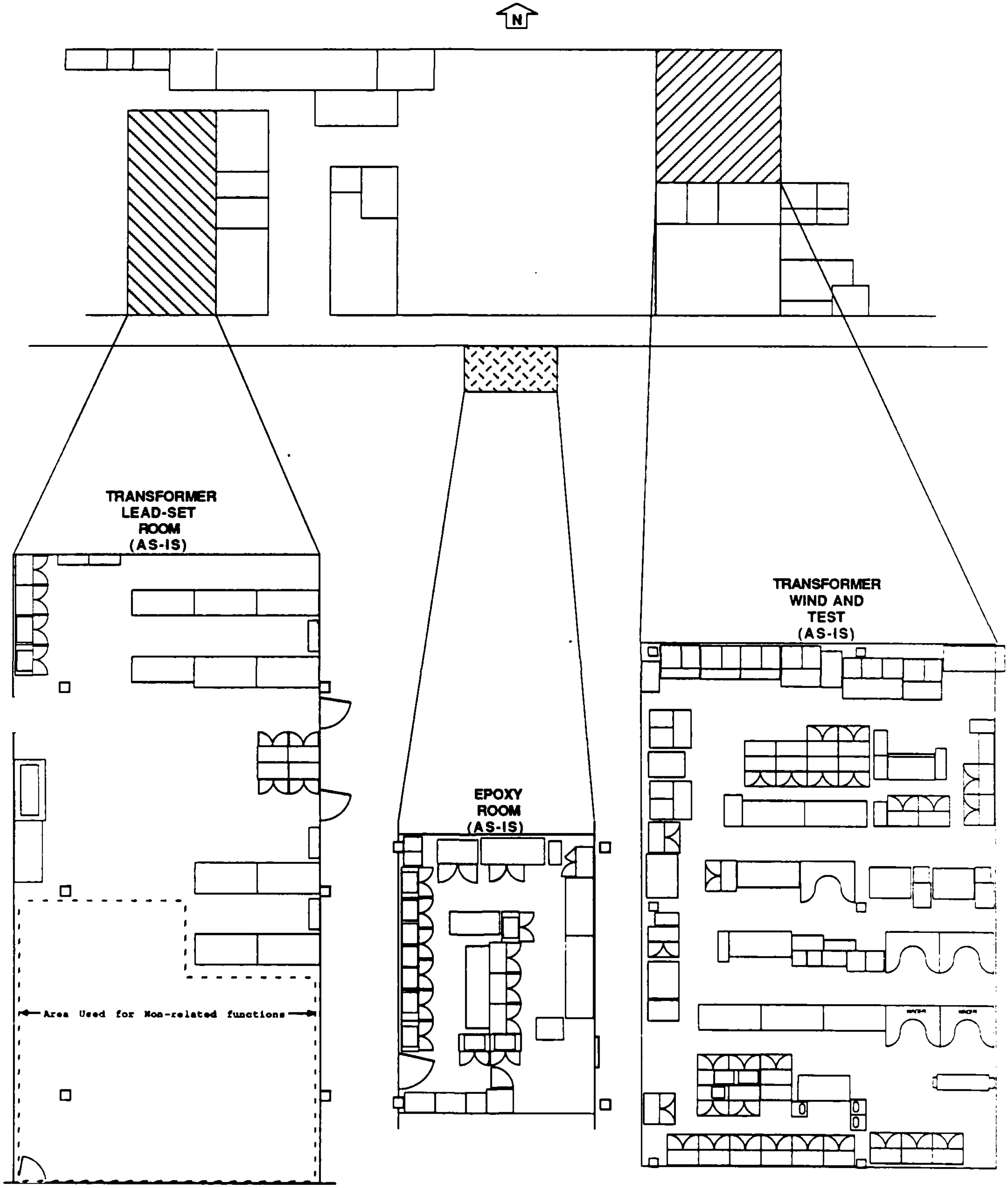


Figure 4.5.2-1 Transformer Production Areas (As-Is Floor Plan)

4.6.1 Chassis Area Production/Process Flow

The Chassis area process flow is graphically depicted in Figure 4.6.1-1. In addition to developing the "generic" process flow depicted here, an operations/part number matrix (described in Sections 3 and 7) was developed to provide a more specific definition of the particular product flows in the chassis area. While Figure 4.6.1-1 highlights a relatively straightforward process flow from kitting to staking and riveting to mechanical assembly, wire wrap, final assembly, and test; the actual process flow in the physical environments of FM & TS are not laid out in as straightforward a manner.

The process flow in the chassis area can be characterized by a number of factors which impede an uninterrupted process or production flow. In launching production of a specific chassis, there is a significant amount of local kitting which requires additional storage of materials and an extensive manual effort to associate documentation with materials delivered from the stockroom. As production continues, there are multiple material queues because the step-by-step process is inhibited by the physical constraints of the area.

In regards to the physical constraints of the chassis area, Figure 4.6.1-2 shows the flow from pre-wire wrap to wire wrap, Figure 4.6.1-3 shows the flow from wire wrap to post wire wrap operations, and Figure 4.6.1-4 shows the flow from post wire wrap to DITMCO test. It is clear from these pictorial descriptions of the production flow that there is much overlapping of activities and not a clear definition of the process flow. In general, these figures depict:

1) No clear dedication or specific organization of work surfaces. (Any of the workbenches may be used for kitting and pre- or post-wire wrap operations depending on the chassis type being produced.)

2) Excessive criss-crossing of the area to complete assembly operations from start to finish

3) Backtracking of production rather than a straight line flow dictated by processes

4) Tooling, materials, and prep areas require inordinate amount of movement

In addition to the physical production flow constraints within the area, there are two additional restraints which impede production. These are both characterized as remote operations consisting of machine group operations and inspection.

The machining operations (i.e., riveting, staking, etc.) are accomplished by a specific group dedicated to performing these operations for several Divisions within the Honeywell facility at St. Louis Park. The machine group operations include processes which may occur prior to material delivery to the

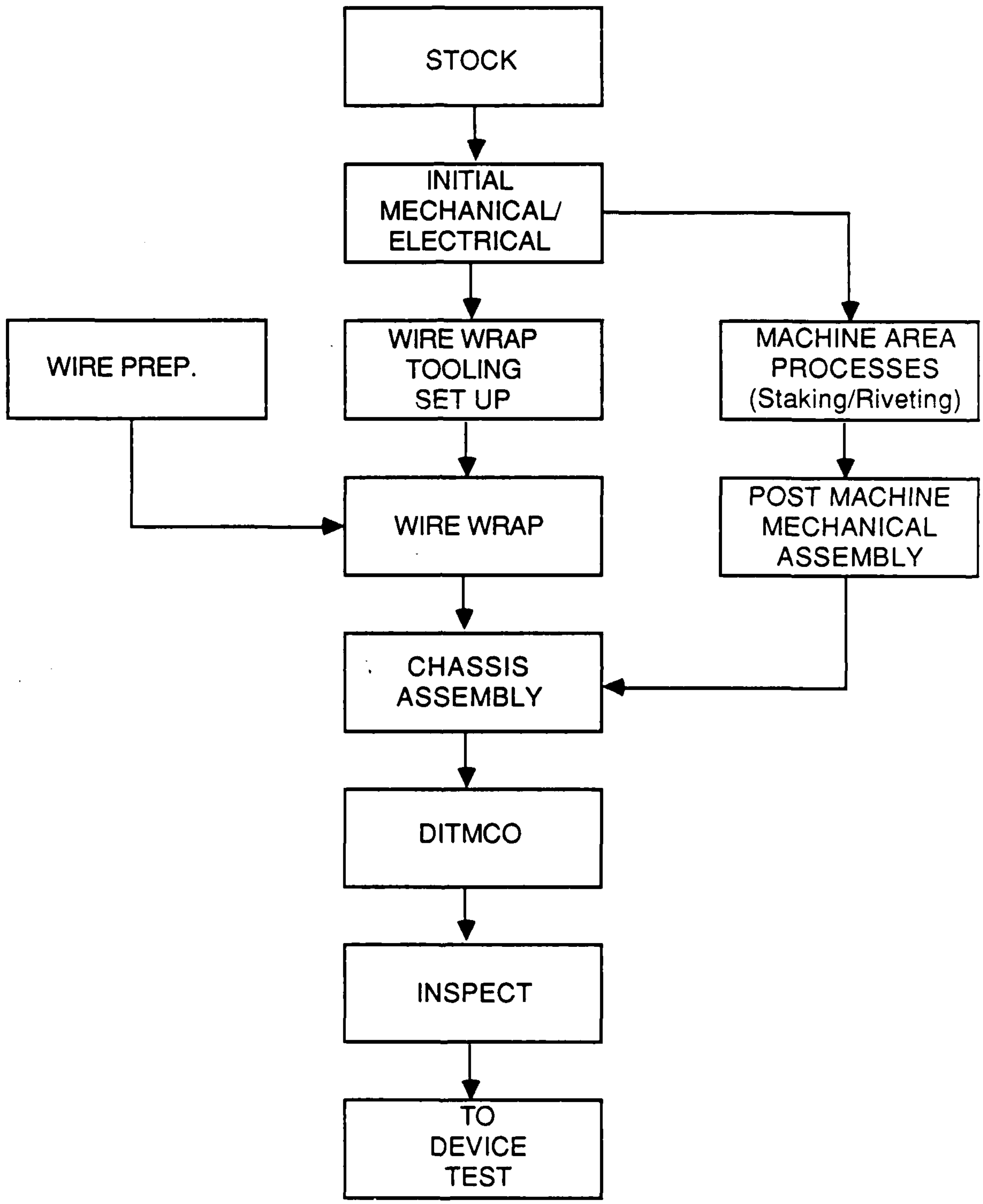


Figure 4.6.1-1 "Generic" Chassis Assembly As-Is Process Flow

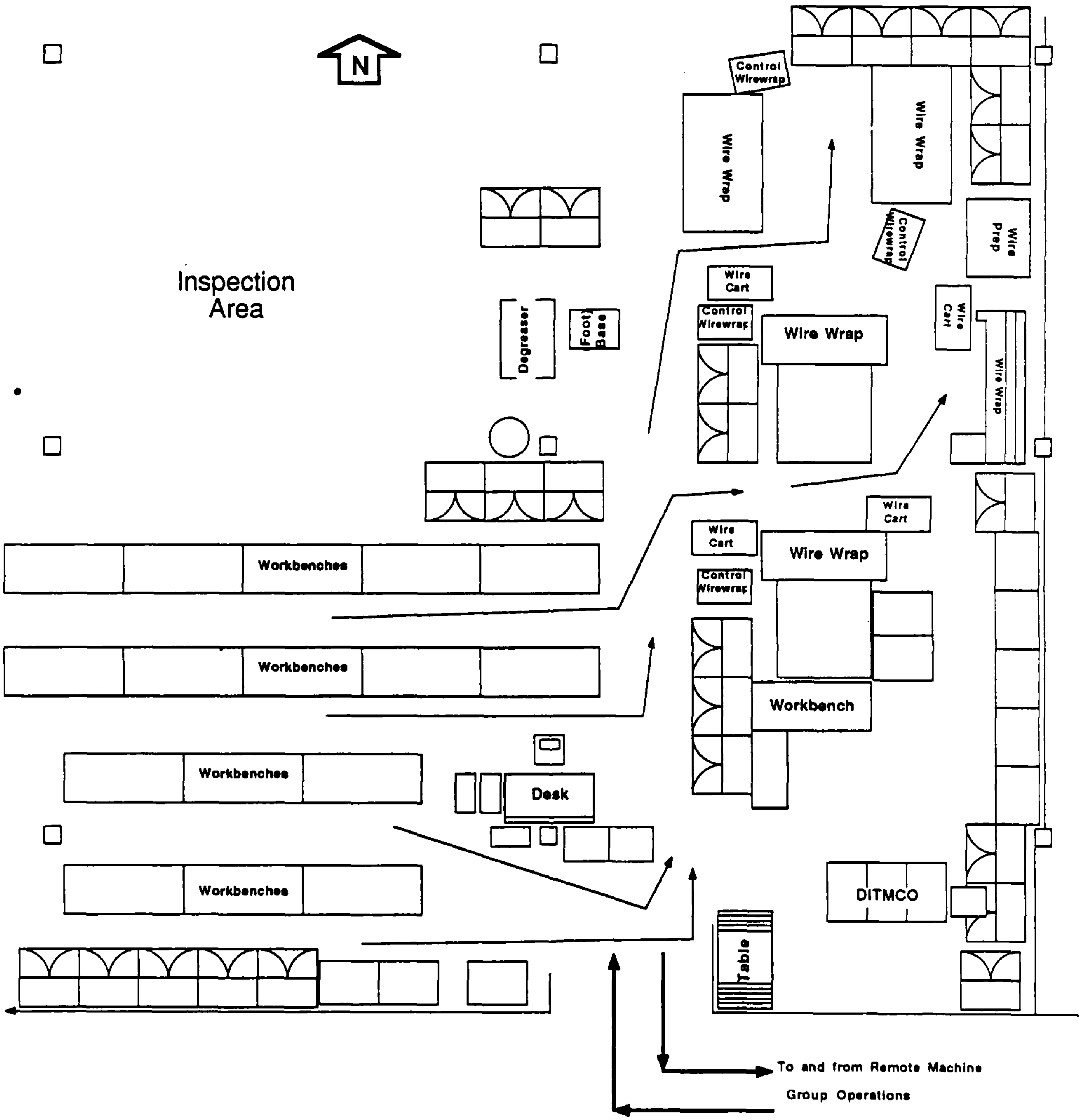


Figure 4.6.1-2 Current Pre-Wire Wrap to Wire Wrap Chassis Production Flow

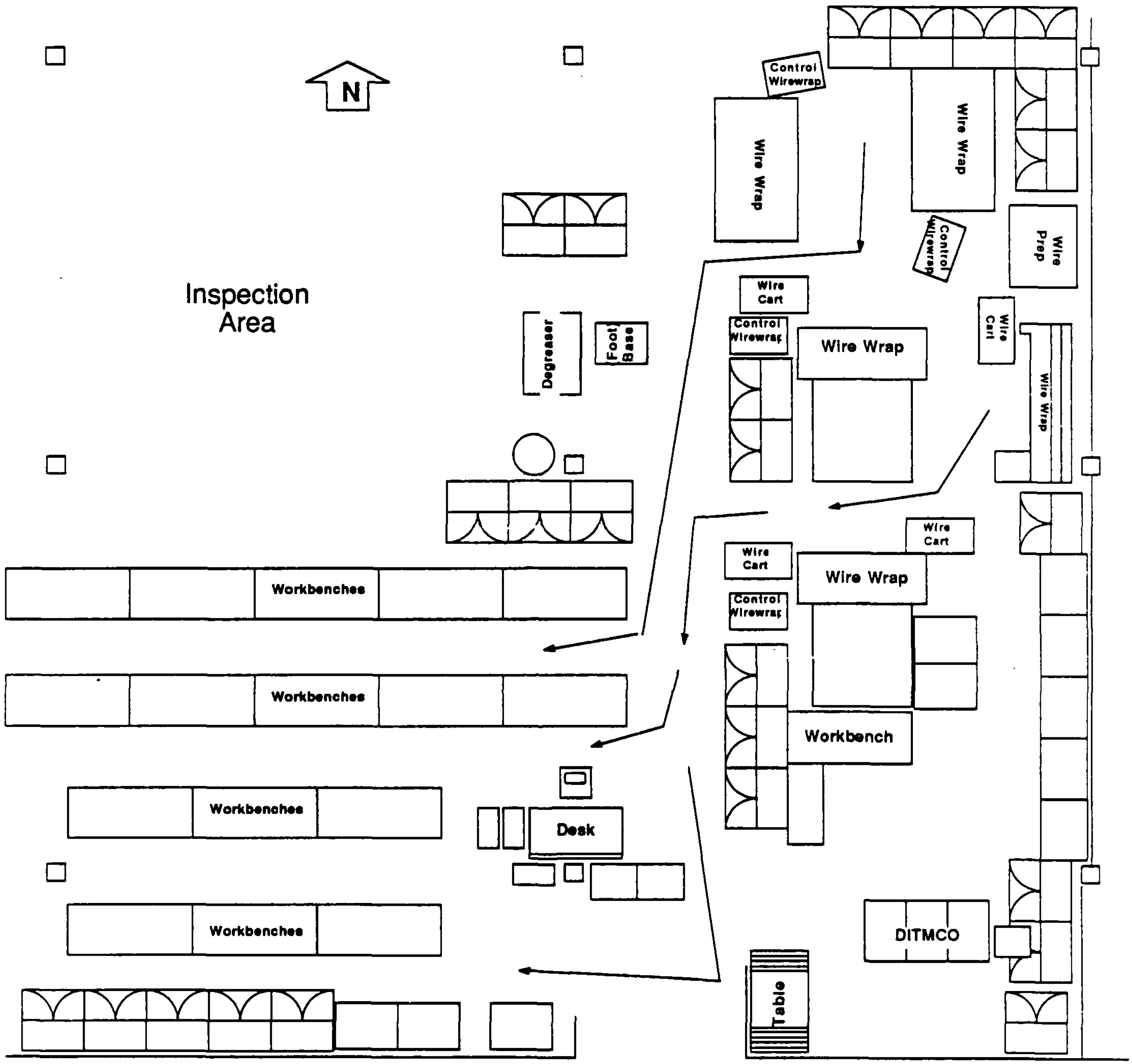


Figure 4.6.1-3 Current Wire Wrap to Post-Wire Wrap Chassis Production Flow

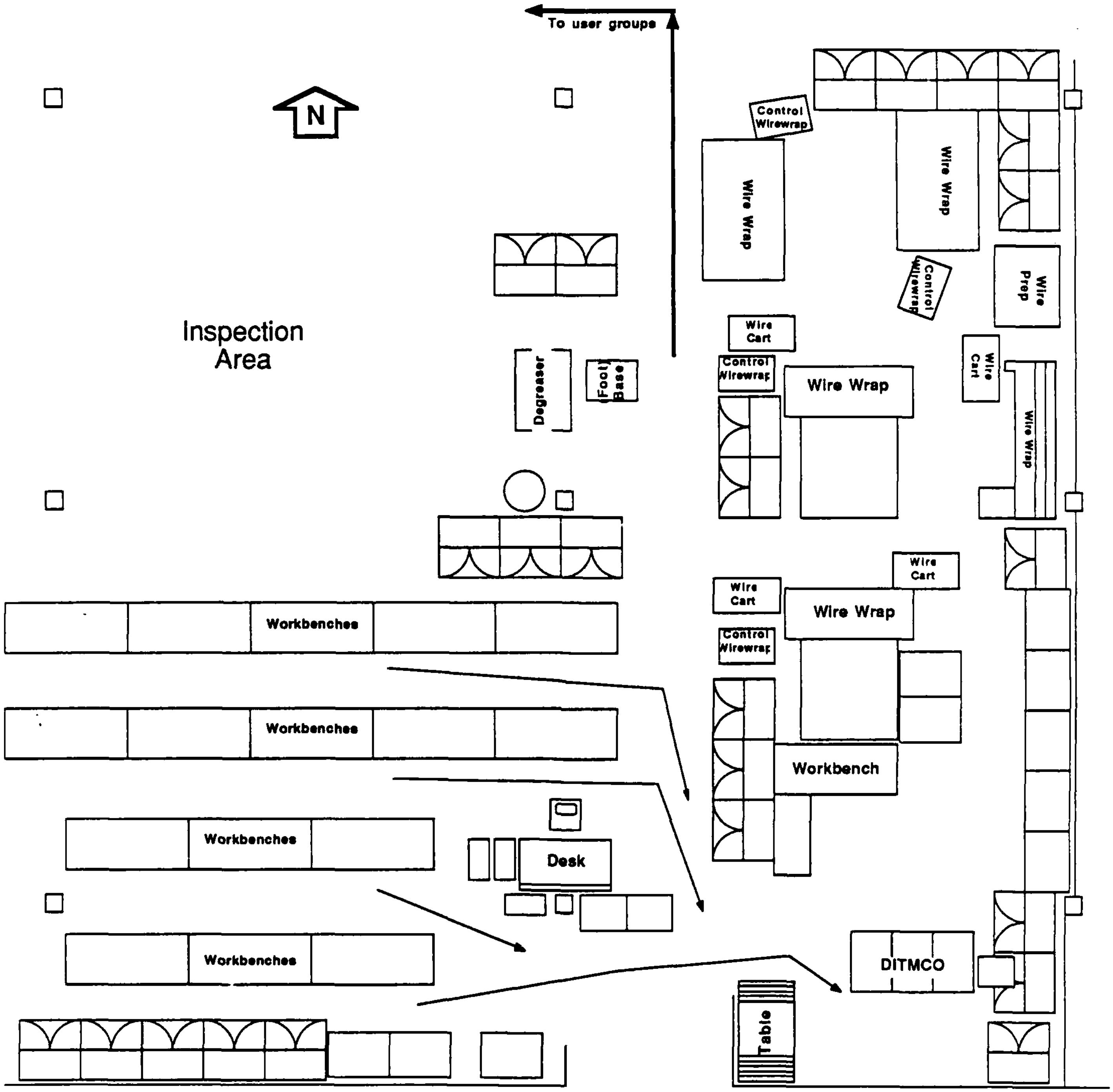


Figure 4.6.1-4 Current Post Wire Wrap to DITMCO Chassis Production Flow

chassis area or those performed initially after kitting or at some point during the manufacture of the product.

There are several constraints imposed by the "outside" machine group operations, but the greatest impact is that the group is located in a remote area approximately 550 feet from the chassis area and all production work routed there must be handled by the stores personnel in the normal course of their pick-ups and deliveries. In addition to the increased processing time due to stores, there are also delays due to the fact that the jobs from chassis are queued with jobs from other operational areas. Typically, a minimum of two weeks is allotted to process work through this group.

The inspection area is also remotely located from the process flow although not physically very far from the chassis production area. However, the location of the inspection area requires that work be diverted from the process flow to a dedicated inspection location to obtain the required certifications. Inherent in this diversion to a separated inspection area is the queue time required by the inspection area of approximately two hours (maximum).

4.6.2 Transformer Area Production/Process Flow

The transformer area is characterized by the fact that while a great number of different parts are produced, they all can be typically described by a "generic" process flow. Figure 4.6.2-1 presents a pictorial description of the process flow within the transformer production area. While this description encompasses a number of individual processes, many of these are or can be consolidated and performed at individual stations or work cells. The primary operations include winding, leadsetting, epoxy, and testing.

While several operations are performed at single workstations, the physical constraints of the transformer area are significantly different and unique from those in the chassis area. Primarily, the major physical constraint on the process flow for transformers is the geographic isolation of processes. As shown in Figure 4.6.2-2, the winding and test operations are located in one separated location, the leadsetting in another, and the epoxy operations in yet another distinct location. This requires a great deal of manual tracking of production as well as the movement of production across corridors by the stores organization.

In addition, the geographic separation of the transformer areas increase queue time between processes and makes scheduling a much more time consuming task. This particular process flow also requires that a number of flows criss-cross which introduces even longer queues.

4.7 FM & TS Material Flow

The material flows for both the chassis and the transformer areas are presented in the following section. However, because the scope of

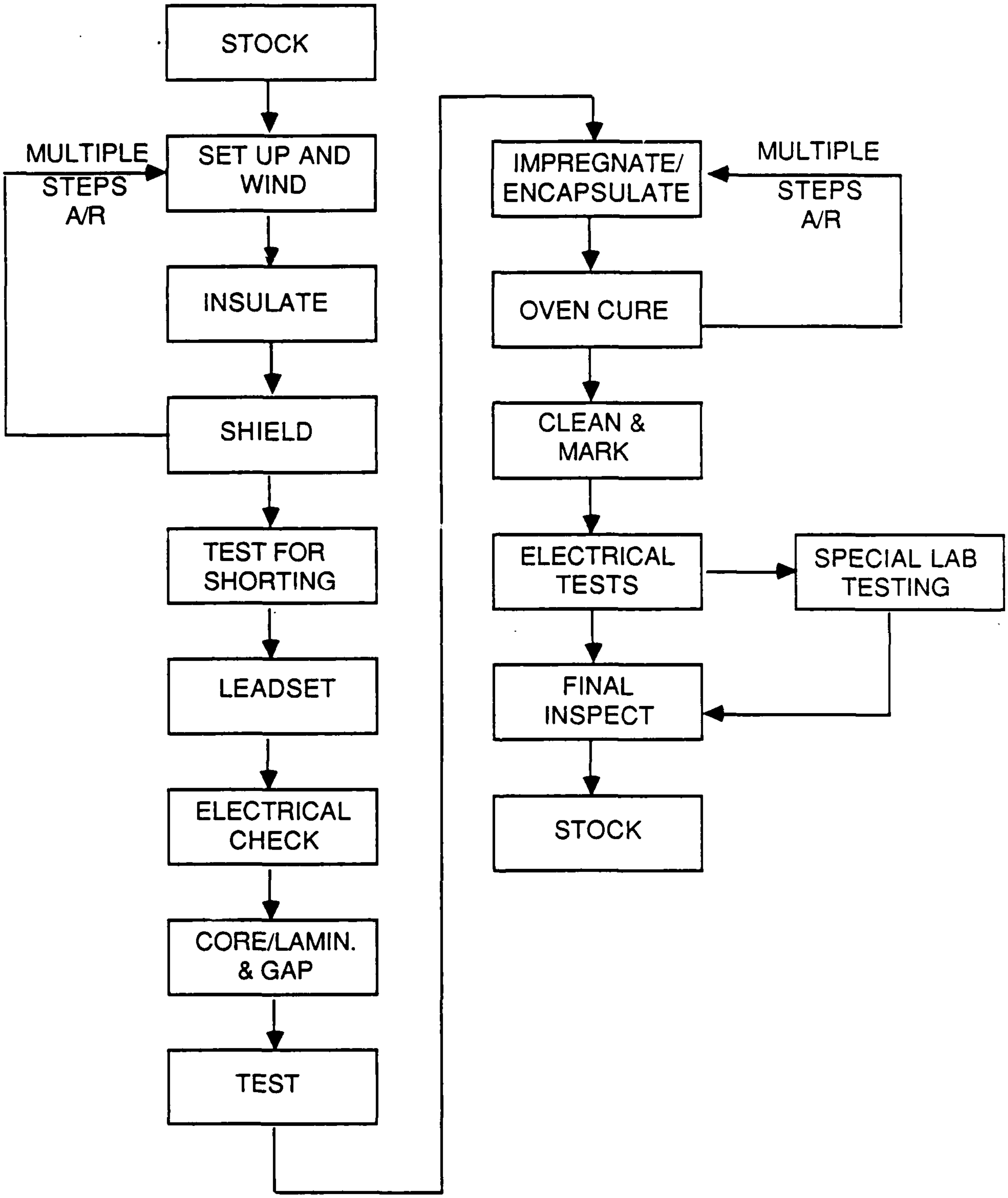


Figure 4.6.2-1 "Generic" Transformer Assembly As-Is Process Flow

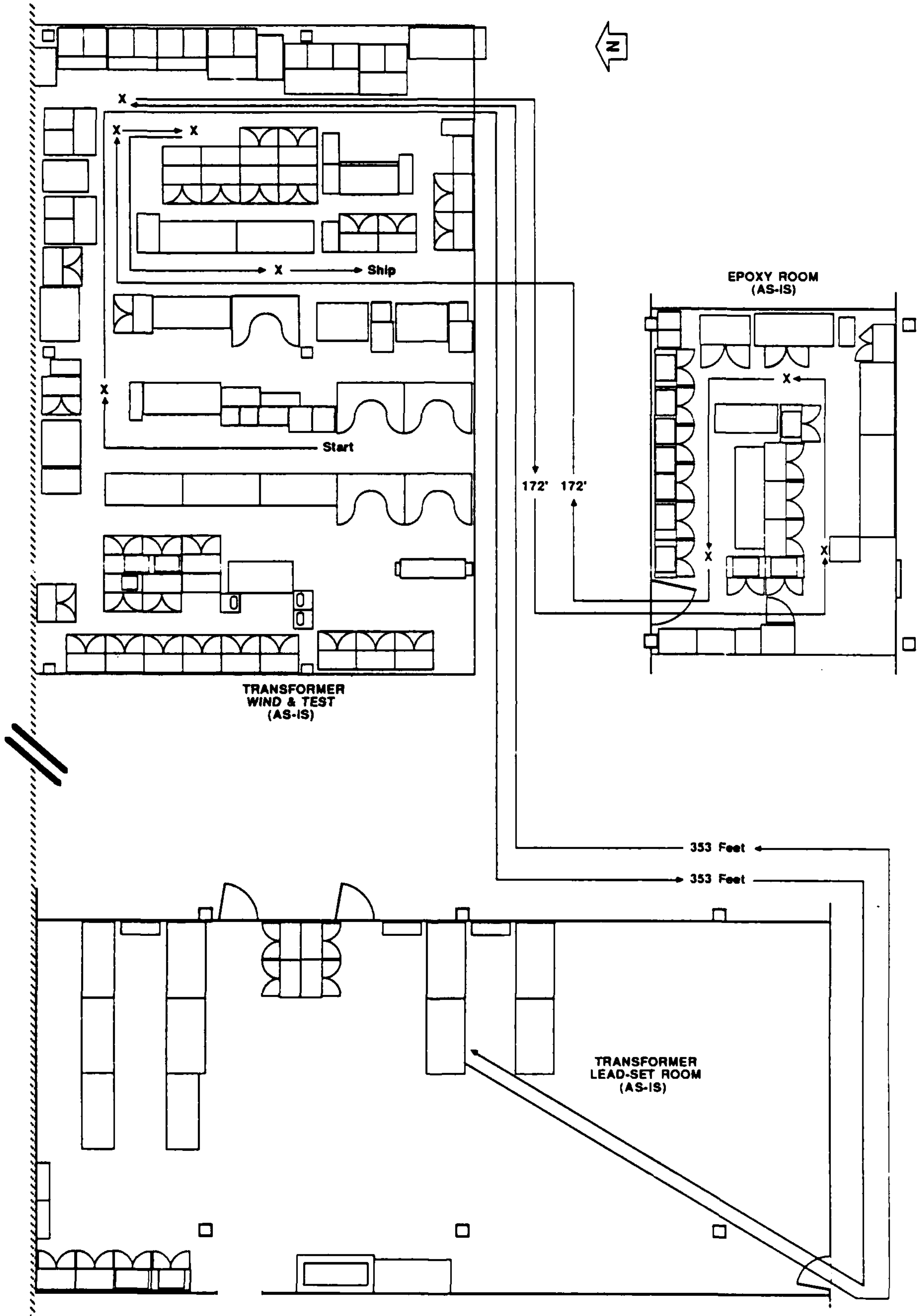


Figure 4.6.2-2 Typical Transformer Production Flow

consideration of material flow is not directly addressed in ITM Project 87, this section provides more of an overview than a detailed analysis.

In general, a number of characteristics can be stated regarding both the transformer and chassis area material flows. One of the major impediments to a smooth material flow, also highlighted in the previous section discussing production flow, is that areas within both chassis operations (machine group, inspection) and transformers (wind and test, leadset, epoxy) are separated geographically. The impact of this on material handling is due to the fact that each of these areas is separated by an "aisle" which by bargaining unit work rules requires transport of work-in-process by the Honeywell stores organization rather than by the transformer or chassis group personnel.

The transport of material by the Honeywell stores organization not only implies delays in the transit time between these areas but also several other factors, including:

1) Possibility of damage to work-in-process in transit between the various production areas

2) Increase in queue times from process to process

3) Inability to define exact scheduling parameters which requires additional carrying of inventory to assure product build

4) Additional efforts required for manually tracking material and work orders

5) Increase in lag time for operators transiting from area to area

A simplified view of the material flow and movement requirements is presented in Figure 4.7-1 for the chassis area and in Figure 4.7-2 for the transformer area. While these figures do describe a "generic" material flow, they do not highlight the material movement means required for this flow or all of the remote operations required for processing production for a number of programs.

The primary means of material movement, whether to other areas or internally within an area, is manual. While, with the exception of the stores movement which is currently unavoidable and out of the scope of ITM Project 87, manual material movement does not greatly impact the material flow, another feature of the areas does. This is the method for material storage.

Currently, material storage in the chassis and transformer areas is performed in a space wasting and time consuming manner. The primary storage areas are cabinets, shelves, under counter of workbenches, and even on top of workbenches when no other space is available. This impacts material flow both from a space wasting perspective as well as inefficiencies due to material location.

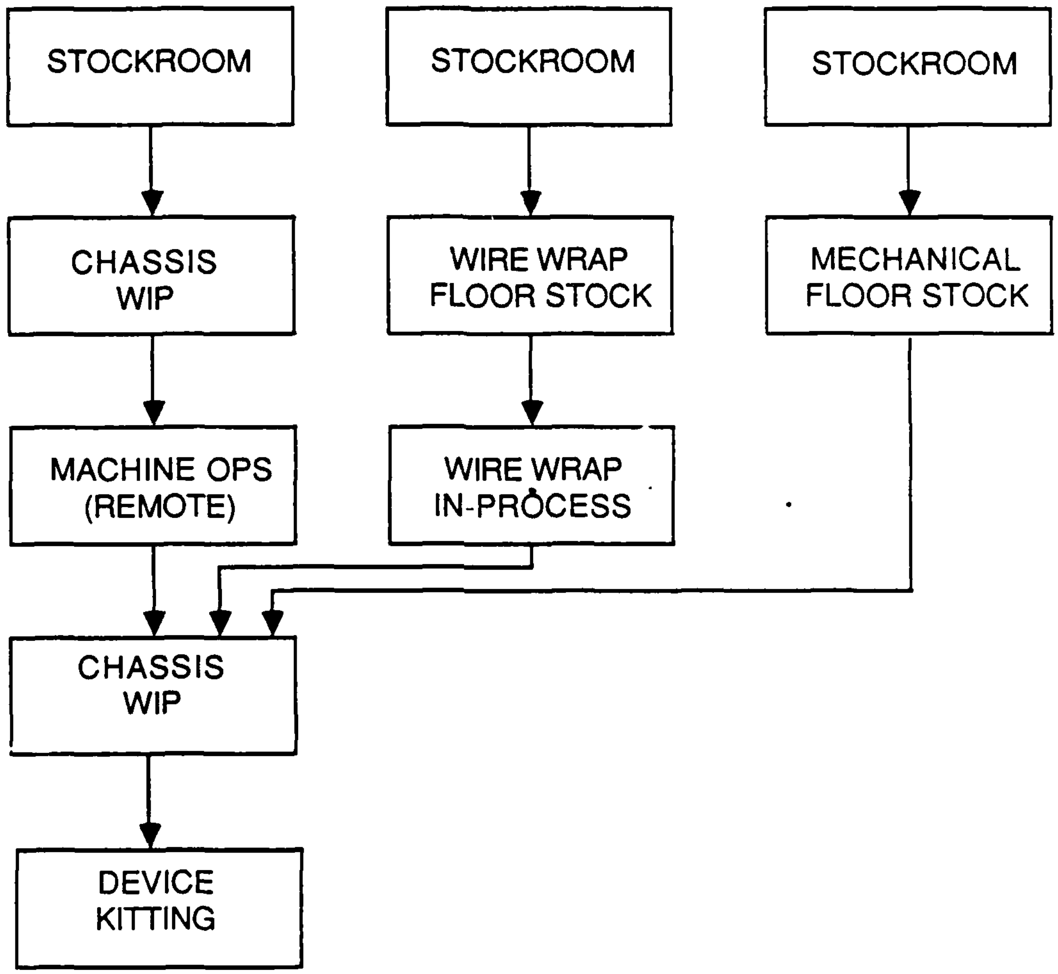


Figure 4.7-1 Chassis Assembly and DITMCO As-Is Material Flow

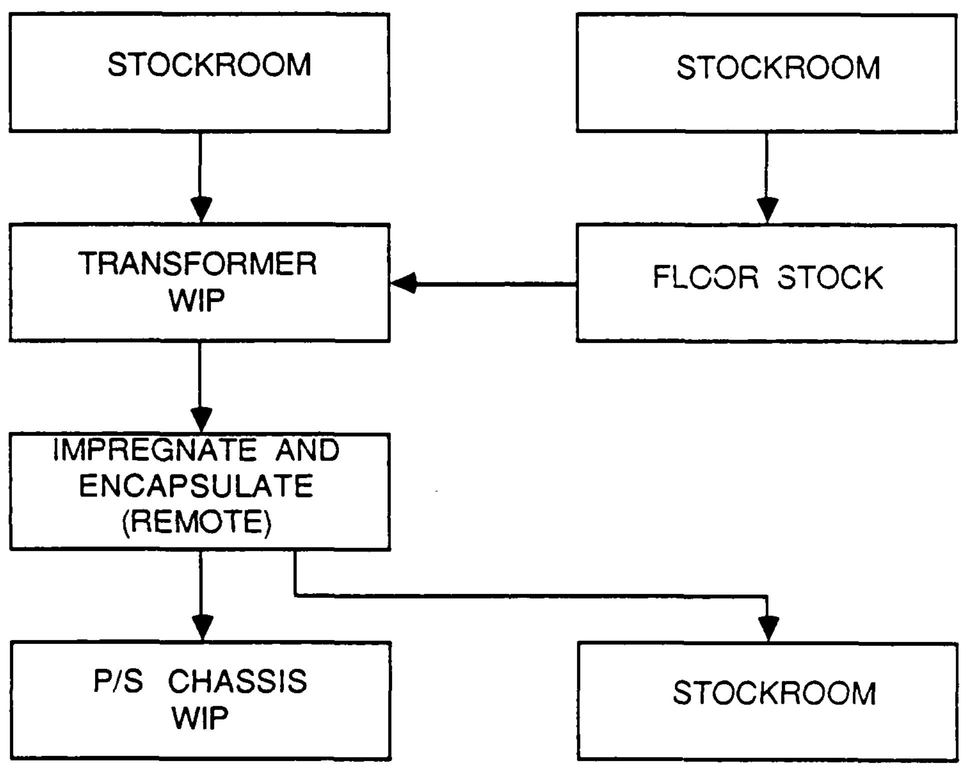


Figure 4.7-2 Transformer Assembly and Test As-Is Material Flow

4.8 FM & TS Information Flow

The information flow within the FM & TS chassis and transformer areas is a blend of manual and automated, or "computerized", systems. Primarily, the higher level systems (which are used company wide) are the systems which have been computerized and the controls and systems in place on the factory floor are primarily manual. The only exception to this distinction is the ATE Central, an integrated testing facility whereby programs are downloaded to specific testing devices. However, the testing performed in the chassis and transformers areas is not integrated with this system.

4.8.1 FM & TS Computerized Information Systems

The primary computerized information system currently at Honeywell is the GAPOS/BOS system. While this is currently in the process of being phased out and replaced by the HMS/BOS system, the functionality of the two systems appears to be approximately the same even though the HMS system will provide a more efficient and powerful computing environment.

GAPOS is a high level business system consisting of a total MRP financial-based computer system. Unlike HMS, GAPOS does not collect any data directly from the shop floor and all of the data transmitted to the shop floor is in the form of paper documentation.

The GAPOS system consists of several modules that are dedicated to specific areas within the system. A block diagram detailing the interrelationships of these modules is presented in Figure 4.8.1-1. The GAPOS system consists of several modules, including:

Bill of Materials which includes all part information for all products manufactured by FM & TS as well as the structures of those products.

Production Process which contains all of the operations descriptions for processes required for manufacturing at FM & TS as well as the production routings of those products.

Financial System which includes all areas concerned with general ledger, payroll, etc.

Procurement Systems which includes all vendor data, purchasing functions, etc.

Customer Order Schedule which processes all customer orders (both booked and forecast) and provides a summary of total product needs.

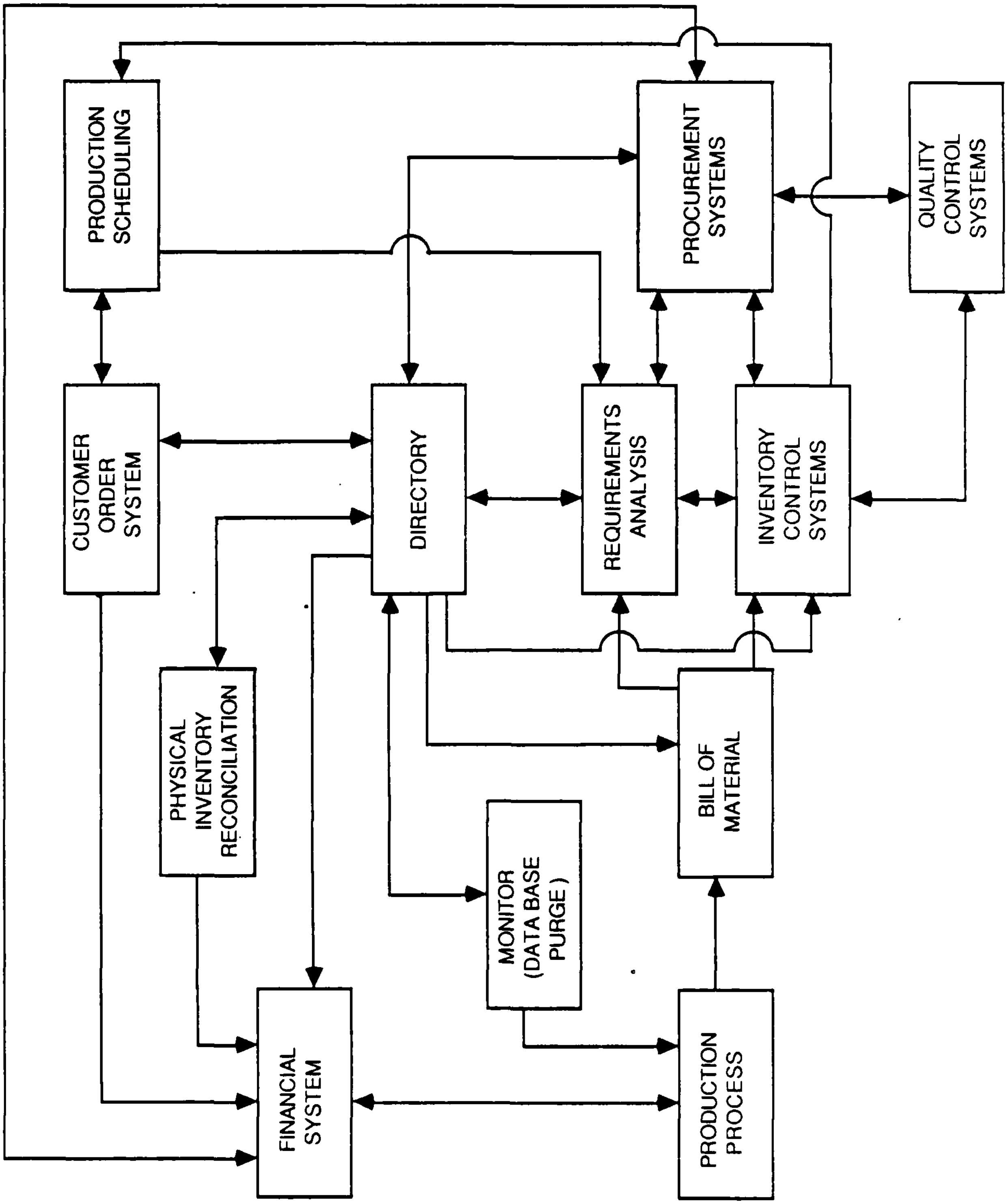


Figure 4.8.1-1 GAPOS System Block Diagram

Production Schedule Analysis which summarizes customer order and marketing forecast requirements, calculates and updates schedules, allows for manual adjustment for leveling schedules and economic order quantities, provides input to Inventory Control Analysis module and promise feedback to Customer Order Scheduling, and records accomplishments against schedules.

Production Planning and Inventory Control modules which converts production schedules for devices and spare parts into requirements for component assemblies and parts and provides sub-assembly schedule requirements by week.

A more detailed description of the generation of the computerized schedules is provided in Figure 4.8.1-2. In this scenario, projected sales and booked orders are fed into the Customer Order System where they are processed and sent to the Production Schedule Analysis module. Here a schedule is generated for the completion of an end item ordered and the order is then released to the Requirements Analysis module which explodes the Bill of Material for all of the items scheduled and processes orders for the required materials.

Following processing by the Production Schedule Analysis module, the end-item schedule is sent to the Production Line Scheduler for manual balancing of the schedule for possible changes dependent upon schedule requirements already developed. The sub-assembly schedule, generated after the requirements analysis has been performed, is sent to Production Planning for the development of more discrete schedules and coordination of material delivery and manufacturing releases.

Other computerized systems within the FM & TS chassis area are used to prepare wire wrap and DITMCO programs for the control of the wire wrapping and testing performed in the chassis area. These systems are stand-alone and are stored on local media used at the individual pieces of equipment.

4.8.2 FM & TS Manually Based Information Systems

Most of the systems utilized on the shop floor for such tasks as production tracking and control, inventory control, etc. are manual, paper-based systems. Manual tracking of work-in-process on the shop floor is performed utilizing several aids, including:

Mats. These are primarily scheduling status sheets which track the manufacture of sub-assemblies (characterized by a specific operation routing/layout sheet) by number of completions by scheduled lot. Production mats are the primary scheduling and tracking devices used on the shop floor.

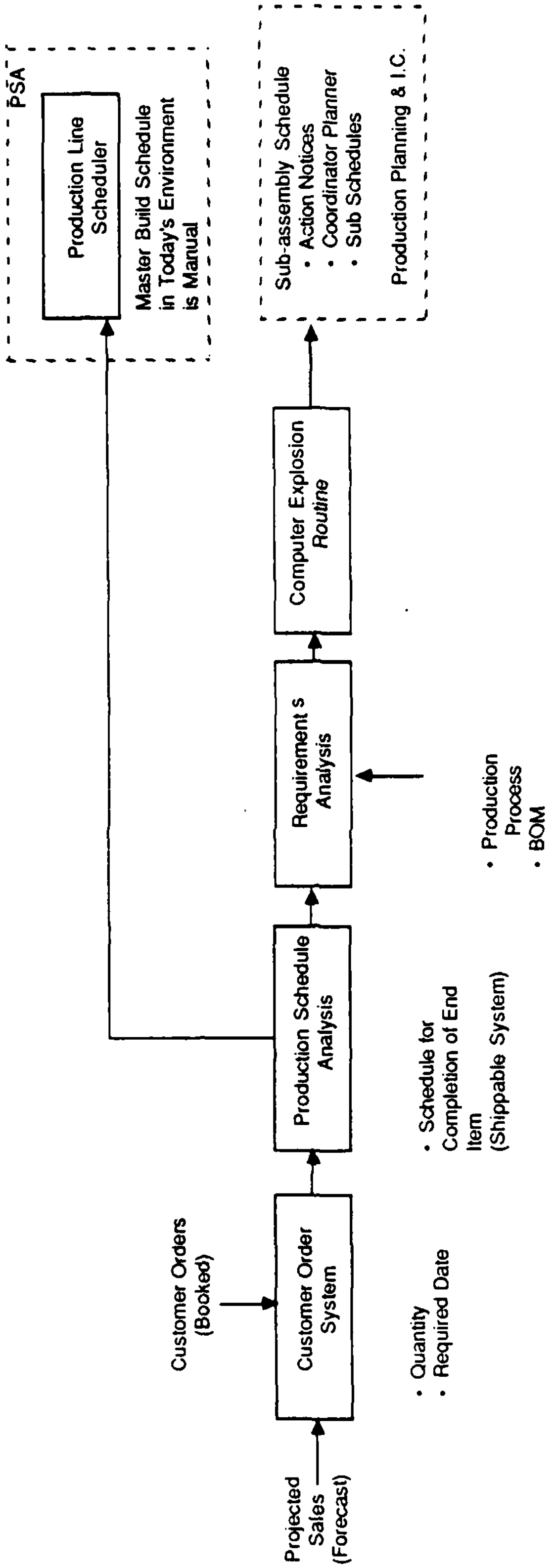


Figure 4.8.1-2 Computerized Schedule Generation

Labor Tally Sheets. As their designation implies, these are used to track the labor charged for work on a specific sub-assembly or assembly as well as to track the type of work that was performed (i.e., manufacturing process, rework, troubleshooting).

Hot Lists. These are used to prioritize the processing of scheduled parts on the shop floor and include blue tags, red tags, and short interval scheduling lists.

The statusing information derived through the use of these production tracking aids is used as feedback to the GAPOS/BOS system. This feedback, however, only occurs at major completion intervals such as the completion of a finished sub-assembly or a device final assembly. This allows both for build-ahead (which results in increased inventory carrying on the shop floor) as well as stocking of finished sub-assemblies until they are scheduled to be completed.

Additionally, some process data is recorded on the shop floor. Primarily, this is in the area of burn-in and test data. Burn-in data is, for the most part, manually generated and tabulated. Several ovens are equipped with temperature cycle recording, but this is not integrated between burn-in ovens and, more importantly, there is no direct feedback to an oven when a setting is out of specification.

Test data, both from the equipment in the transformer area as well as the DITMCO equipment utilized in the chassis area, is primarily collected at the station and is not interfaced to a centralized facility as are the Honeywell ATE testers, which are used for PWB and device testing. All of this equipment is monitored manually. Since units such as the DITMCO and wire wrap machines are computer or controller driven, the result is "islands of automation" because no linkage exists to a centralized database or control facility.

4.9 FM & TS Equipment

The equipment employed in the chassis and transformer areas can be generally characterized as older (though proven) equipment that has remained stable for several years. The primary cause for this is that while certain programs are relatively new and employ newer technologies, the programs which are being built in the chassis and transformer areas are stable and are based on fundamental, established techniques.

The following sections describe the equipment currently being used in manufacturing in both the FM & TS transformer and chassis areas. Included is a description of the equipment, applications, and other specifications as they apply to the specific pieces of equipment.

4.9.1 Chassis Area Equipment

The equipment currently used in the chassis area consists of equipment used for mechanical and electrical assembly, wire wrapping, testing, and several miscellaneous operations. Also included is a characterization of the equipment being used by the mechanical assembly machine group which is not under the direct control of the chassis area.

Mechanical Assembly Equipment

Equipment required for mechanical assembly consists of the normal complement of hand tools, such as wrenches, screwdrivers, nutdrivers, etc., in addition to battery powered screwdrivers.

Electrical Assembly Equipment

Electrical assembly equipment includes soldering irons, wire wrapping tools, holding fixtures, and other miscellaneous tools associated with wire bonding and joining. Many of these tools are part of minor equipment issue to operators and used in day-to-day activities.

Wire Wrap Equipment

There are currently five wire wrap machines in the chassis area. The operational area of each machine is provided with tooling attachment points to clamp sub-assemblies during the wiring process. This equipment performs wire wrapping for the various device base plates and receives data input via eight-level perforated tape.

Additionally, tooling plates are used to correctly position the I/O connectors for wiring. These plates are unique to each device used in FM & TS programs.

Test Equipment (DITMCO)

DITMCO fixturing consists of cable sets used to interface the tester with the miscellaneous chassis under test. This also permits the continuity testing of a variety of wire wrapped assemblies.

Installation of adapter cables into the chassis for continuity testing is manual and requires high insertion forces. Operators are exposed to the potential for "Carpal Tunnel Syndrome" due to methods employed to seat adapter cards in the chassis under test.

Machine Group (External) Equipment

The machine group includes several pieces of equipment that are used to process work-in-process from the chassis area. This equipment can generally be described as older (15 years or more) pneumatically and/or manually operated staking and riveting machines.

Miscellaneous Equipment

There are a number of other miscellaneous pieces of equipment that are employed in the chassis area for performing various operations. A general list of these pieces of equipment includes:

Manufacturer	Description
Baron-Blakeslee	Degreaser
Cannon	Pneumatic Crimper
DEC	PC w/ printer
Gardner Denver	Wire Stripper

4.9.2 Transformer Area Equipment

The equipment currently used in the transformer area consists of equipment used for winding, leadsetting, testing, and epoxy and dirty operations.

Winding Equipment

The transformer/coil fabrication equipment, while of significant age (15-20 years), appears reliably functional. Transformer production volumes are of sufficiently low level resulting in a minimal level of equipment wear. The greatest liability of equipment age is securing repair parts when the inevitable failure does occur.

The winding equipment used in the transformer area can be characterized as electrically driven and controlled with both mechanical and electrical readouts.

This equipment includes:

Manufacturer	Description
Meteor	Bobbin Winder
Levin	Lathe Winder
Honeywell	Hand Winder
George Stevens	Hand Winder
Levin	Lathe Winder
Gorman	Toroid Winder
Leesona	Stick Winder
Leesona	Coil Winder
Gorman	Toroid Winder
Bachi	Bobbin Winder

Leadsetting Equipment

In addition to the required soldering and insulation stripping equipment such as solder pots, fume hoods, abrasive strippers, etc., the leadsetting area utilizes various clamps and fixtures to position magnetic components during lead preparation and termination operations.

Test Equipment

Equipment utilized for testing consists of several large consoles configured to test the more complex attributes of transformers in addition to various smaller testers used to check winding polarities, turns ratios, shorted turns, etc. Miscellaneous equipment such as oscilloscopes, signal generators, frequency meters as well as meters for measuring voltage, power, and current are employed in testing magnetics. Additionally, much of this same equipment is incorporated into the test consoles.

The variety of manual transformer testers requires time-consuming setups and movement of parts from tester to tester depending on parameters measured.

The test consoles include:

Manufacturer	Description
Honeywell	Transformer Test Stations
Honeywell	Magnetic Station

Ovens

The oven equipment is used to cure and/or prep transformer area products for encapsulation, impregnation, and coating. One oven is associated with the test stations for transformer and inductor burn-in. These ovens encompass a large variety which are all manually controlled.

This equipment includes:

Manufacturer	Description
Precision	Ovens
Despatch	Oven
Tenney	Ovens

Epoxy, Dirty Room , and Miscellaneous Equipment

The following equipment is used in either the "dirty" room (in which operations that produce unusual contamination opportunities are performed), epoxy operations, or in one of the transformer winding, leadsetting, or test areas. This equipment includes:

Manufacturer	Description
Honeywell	Vacuum Chambers
Sears	Refrigerator
Silver King	Refrigerator
Environmental	Cold Box
Hewlett-Packard	Vector Meter
DoAll	Band Saw
Challenge Machine	Paper Cutter
LabConCo	Fume Hood

SECTION 5

"TO-BE" PROCESS

The following section describes the "To-Be" processes that will be in place as a direct result of ITM Project 87. In addition, several areas are described within the FM & TS chassis and transformer environments that, while not directly affected by the improvements incorporated for ITM Project 87, either provide the groundwork for the improvements developed or are tangentially affected by the efforts dedicated to ITM Project 87.

The primary emphasis of ITM Project 87 is on the improvement of processes and the upgrading of assembly and test equipment. Other areas described briefly in this section include:

- FM & TS Floor Plan Development
- Material Flow
- Information Flow

5.1 "To-Be" Operations Overview

The "To-Be" operations for the chassis and transformer areas include improvements in the layout and material handling methods used in the areas as well as improvements in production, assembly, and test equipment described in the following section. While all improvements are described in general in this section, the emphasis of the following section is upon process, test, and equipment improvements.

Figure 5.1-1 presents an overview of the "To-Be" processes required to produce FM & TS products.

5.2 FM & TS Area Floor Plans

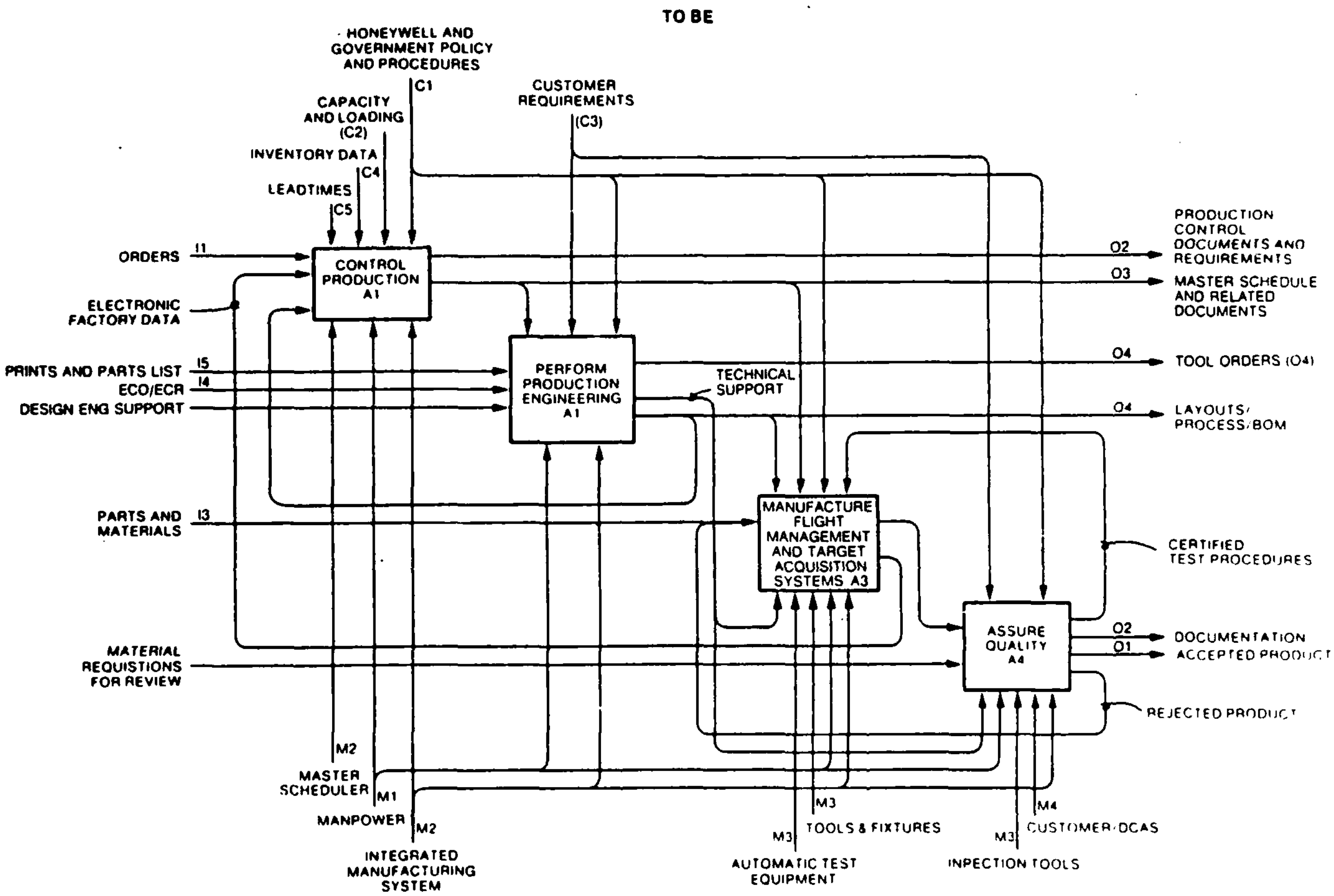
The floor plans designed for the chassis and transformer areas were developed by ITM Project 88 and are presented here for reference purposes. Figure 5.2-1 depicts the location of the "To-Be" Chassis, Transformer, and Epoxy areas within the overall Honeywell St. Louis Park facility.

5.2.1 Chassis Area Floor Plan

The floor plan developed for the chassis area is presented in Figure 5.2.1-1 and can be characterized as providing the following features:

1) Wide aisles have been included to facilitate the ease of work flow.

2) Wire wrap units have been clustered to allow for ease of access for wire wrapping operations and arranged by frequency of use.



A0 Produce Flight Management and Target Systems (FM & TS)

Figure 5.1-1 "To-Be" Production Process (FM&TS)

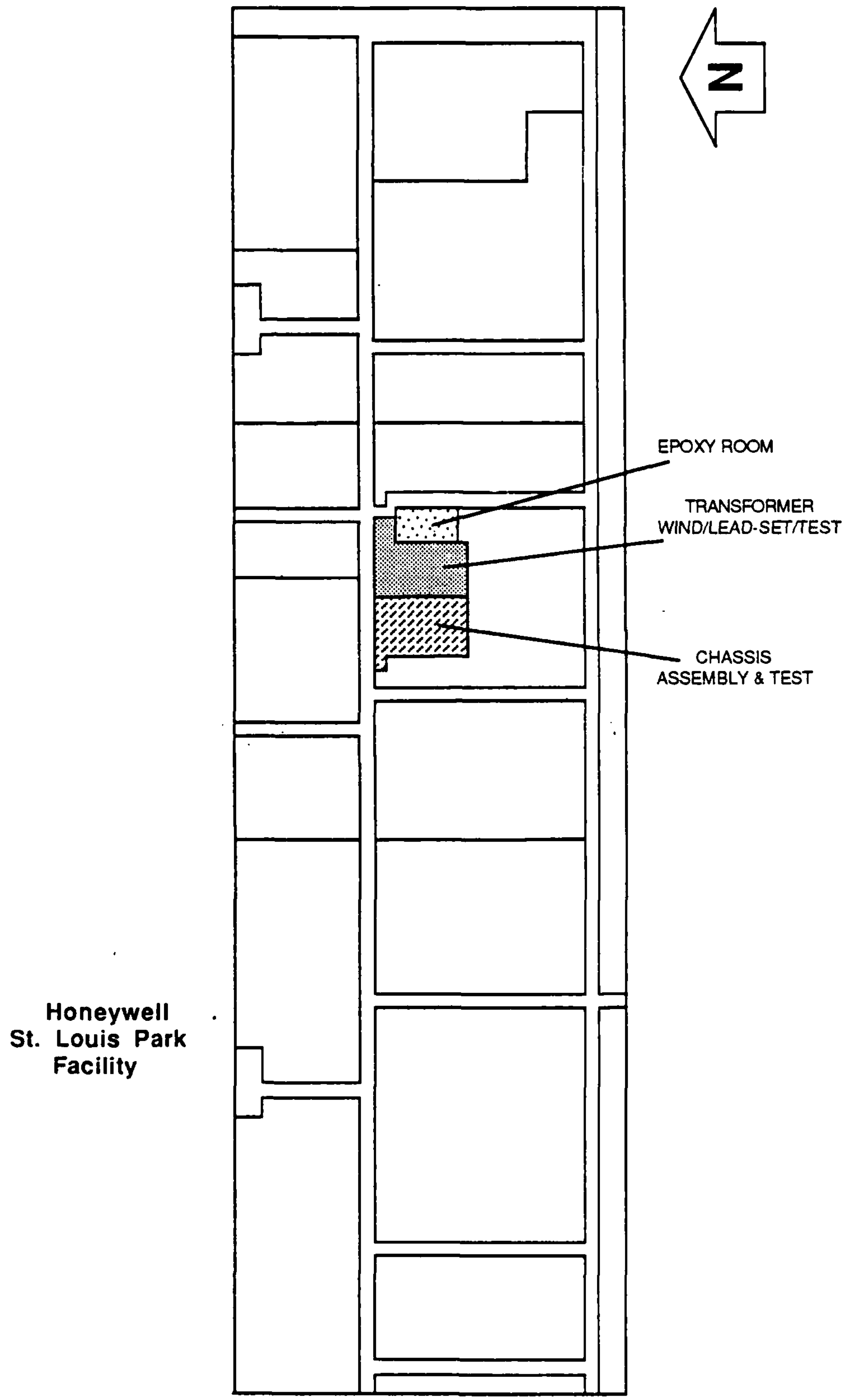


Figure 5.2-1 Chassis & Transformer Areas To-Be Location

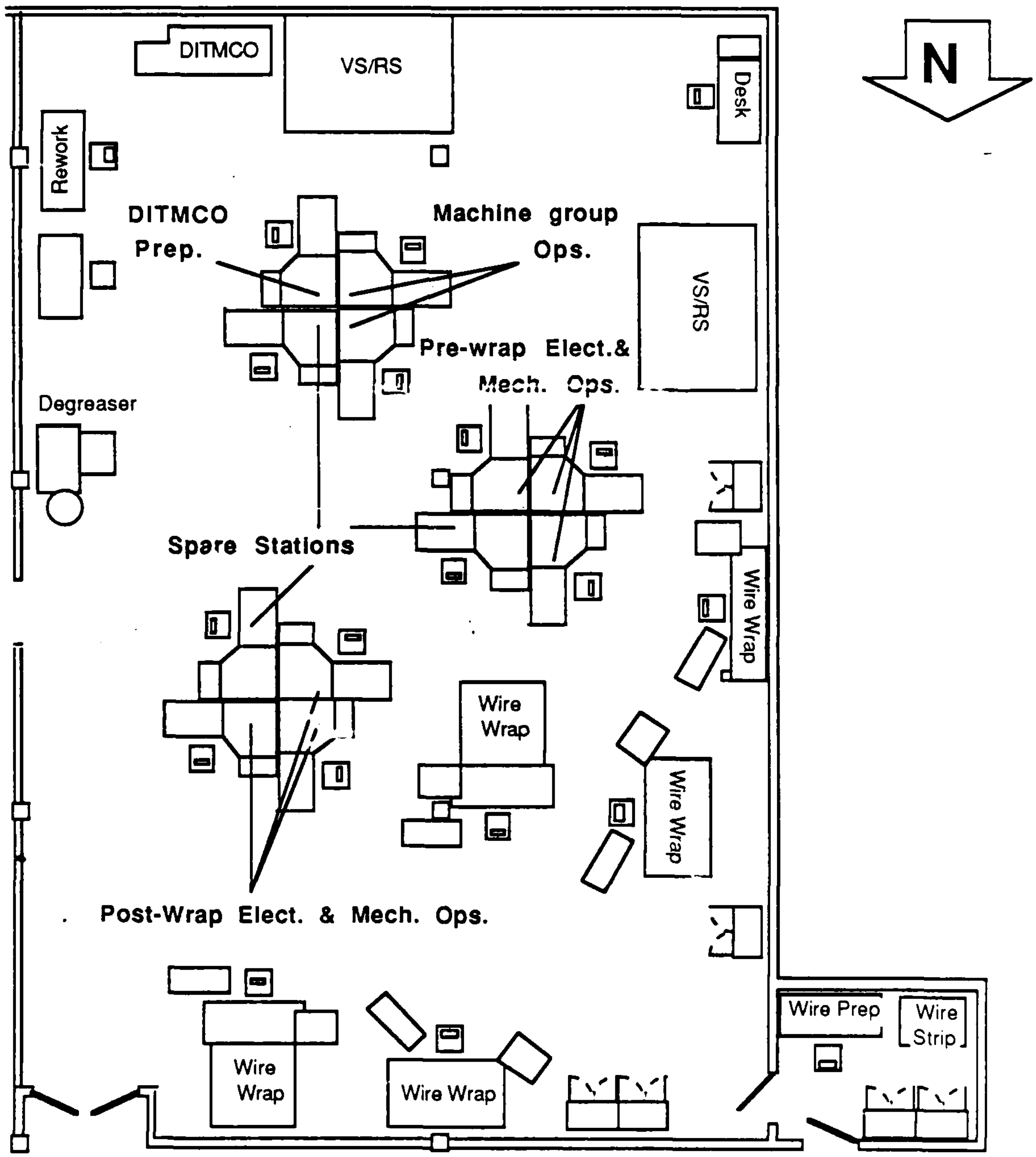


Figure 5.2.1-1 Chassis Area Layout

3) VS/RS storage units are centralized at wire wrap operations to provide storage of wire wrap adapter plates and supplies and at the DITMCO tester for adapter and work-in-process assembly storage.

4) Assembly stations are arranged for a smooth flow from operation to operation.

5) Spare work bench surfaces are distributed to allow for work load peaks and new product development areas.

6) The DITMCO tester is located in a direct path to the main area entry point to provide free access for outside work.

7) Wire preparation activities are located in a separate, isolated room.

8) Machine Group Operations have been incorporated into the area.

9) Work benches are clustered to provide functional workstation grouping.

5.2.2 Transformer Area Floor Plan

The floor plan developed for the transformer area is presented in Figure 5.2.2-1 and can be characterized as providing the following features:

1) Transformer area is generally laid out to provide a smooth flow from wind to leadset and/or test followed by the necessary impregnation and encapsulation operations.

2) Layout is configured with more than adequate aisle space so that variations in process requirements from assembly to assembly do not pose significant flow problems.

3) Winding area is laid out so that machinery with high utilization is grouped in a centrally located "island."

4) One VS/RS unit is positioned in close proximity to the winding area to provide wire and coil form supplies to the winding cell (this unit could optionally be configured to be restocked from the back, if desired)

5) The second VS/RS is located near the leadset operations to provide supplies support and work-in-process storage.

6) A third VS/RS is located in the epoxy room for supplies storage.

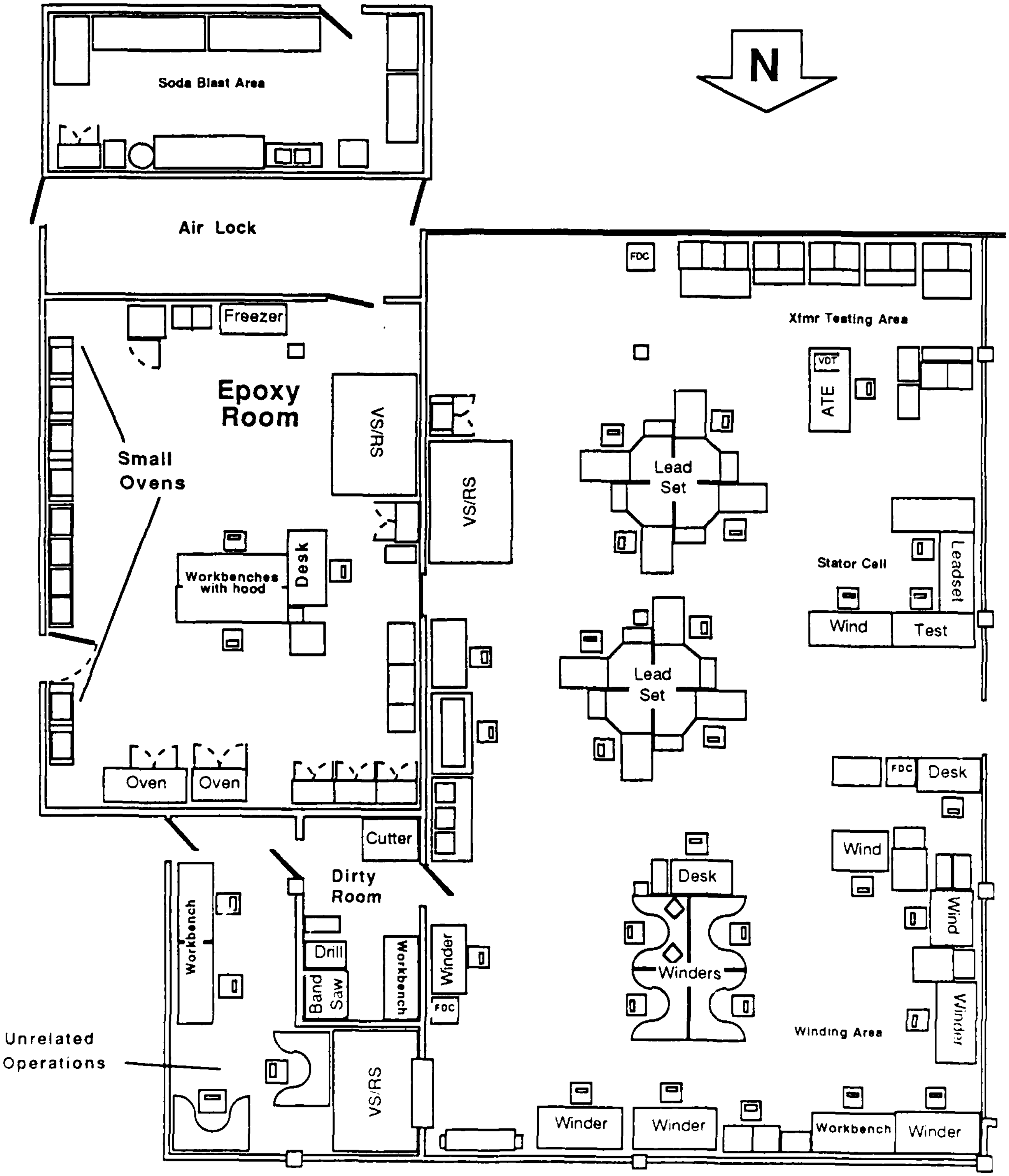


Figure 5.2.2-1 Transformer Area Layout

7) The epoxy room is shown as being located outside the current "airlock". Parts are moved to and from this area through a slide up window. (Alternately, if the airlock/clean room environment is not required, an access doorway could be provided at this location).

8) A small room is provided for "dirty" operations in the transformer area. Additionally, this room can function as an "airlock" for the transformer area as an alternative to the existing access ways.

9) Existing soda blast room has been re-oriented to allow an improved layout and placement of the epoxy area.

10) Epoxy room has been re-oriented to provide additional aisle space with a centralized bench area. Curing ovens are grouped along the walls toward one end of the room and clustered around the bench "island" so that work can be prep'd and moved back and forth between ovens and work surfaces.

11) Provisions have been made to accommodate all existing transformer test equipment as well as the ATE unit specified in this document. Eventually, the use of most of the manual testers can be eliminated when programs and fixtures are developed for the new ATE nit.

5.3 "To-Be" Production/Process Flow

The "To-Be" production/process flow is presented in the following sections. One of the major improvements in the optimized design of the production/process flow for each of the areas is the development of a straightforward production flow that is aligned with the process flow. Additionally, in the transformer area, the consolidation of the geographically distinct operations will result in significant production flow improvements.

5.3.1 Chassis Area Production/Process Flow

The chassis area in the "To-Be" configuration integrates the sequential processes necessary to produce a finished chassis for the various military programs so that duplication of stations is unnecessary to ensure uninterrupted product flow.

Each wire wrap plate passes through a series of stations to and from wire wrap depending on the necessary preparation or post wrap work. Since no program volume is sufficient to fully utilize a given station (except wire wrap), the process orientation allows significant labor consolidation. Similarly, in chassis build-up, tooling and parts are centralized and material stocking can be concentrated in storage systems (e.g., VS/RS) to save transit, search, and picking times.

5.3.2 Transformer Area Production/Process Flow

A survey of the top eighty percent of transformer assemblies and subassemblies produced during 1986 was performed to establish the transport profile for the area and determine the resources required to move these parts through the production process.

The transport between the respective operational areas consumed an estimated 1474 hours during 1986. This is important in two respects. The consolidation of the separate areas could potentially reduce the stockroom allocation to FM & TS. And, delays in processing and the effective application of FM & TS transformer personnel will be positively impacted as a result of maintaining uninterrupted production flow.

Intra-area movement provides minimal savings. This is a result of the relatively small number of transformer/subassembly lots processed. The comparison of flow distances within the "As-Is" and "To-Be" layouts resulted in a five percent transport reduction.

Additionally, the project team believes, and current industry experience bears out, that the combination of consolidating the respective transformer operations and developing ergonomic work cells will result in productivity gains in excess of ten percent per year.

5.3.3 Inspection Process Improvements

The advanced inspection strategy for implementation at Honeywell's FM & TS chassis and transformer area is detailed in a step-by-step procedure in Section 8 of this document.

Incorporation of an in-line Quality Control system coupled with savings due to elimination of time associated with transporting parts and/or waiting for inspection as well as start/stop losses and rework losses should more than offset inspection time added in the process. Conservatively, time spent on inspection after 1988 should decrease from over 4% to 2% of expended hours.

5.4 "To-Be" Material Flow

The improvements in the "To-Be" material flow were developed by ITM Project 88. In general, a number of characteristics can be stated regarding the improvements in both the chassis and transformer areas. The most important improvements in the material handling for both of the areas involves the operations, a majority of all of the material in these work areas will be stored in Vertical Storage and Retrieval Systems (VS/RS). This reduces the floor space utilized significantly and consolidates material into specific areas adjacent to the materials' points of use which reduces the material movement travel time.

Another significant improvement associated with the implementation of the VS/RS units is the purchase of a computer-driven material locating system for each of the VS/RS units.

Other material storage and handling equipment will aid in optimizing the material flow in the chassis and transformer areas. These include workstation storage bins for small parts and miscellaneous equipment as well as dedicated work carts for transporting material.

5.5 "To-Be" Information Flow

The most significant improvements in the chassis and transformer area information flow will be achieved with the introduction of the HMS/BOS system currently being modified for use at the St. Louis Park facility. While on a conceptual level this system performs all of the same processes as the GAPOS system, the increase in functionality is significant. Because the two systems are similar in the types of functions they will be performing and the final definition of the system has yet to be implemented, the focus of this section will be primarily on the introduction of the Factory Data Collection system and the improvements outlined in this report that can be even further upgraded due to their selection for interfacing with a work center controller.

The Factory Data Collection (FDC) system has been developed as a means of automatically recording hours an employee expends on a specific operation/part number. This provides important information to FM & TS management both for accounting purposes as well as monitoring the percentage of completion of a specific part being built. It is envisioned that in the future, the FDC system will be expanded to provide location tracking of work-in-process as well.

Improvements that have been included in this report that can be further upgraded for interfacing with a currently envisioned work center controller include:

- Pneumatically powered torquing tools. These tools have an RS-232 interface and torquing requirements can be downloaded from a higher level controller when a specific operation has been indicated as being performed. This indication could come through the bar code wanding of a production routing sheet or the on-line touchscreen interface request to perform an operation.

- Material Storage and Retrieval System. Location look-ups can be directed by a higher level controller based upon an operator's request for the next job to be processed.

- Oven Monitoring Network. Temperatures and cycle times can be downloaded from a centralized computer database for each part number to be cured.

- ATE. Transformer and Chassis area ATE equipment can be networked in the future in the same manner that the H2600's are networked in the current FM & TS Card and Device area.

- Other Equipment. It is conceivable that even the ink jet marking in the transformer area as well as the wire wrap machines in the chassis area could be interfaced to a work center controller for more complete control and monitoring of operations within the respective areas.

One other program which is currently under evaluation for Honeywell's MAvD is the introduction of a "factoryvision" system (ITM Project 32) which will present production layouts and other production related information to each of the operators on the shop floor. This type of system, interfaced with a work center controller would raise Honeywell's operations to the most advanced, state-of-the-art achievable with the computing technology available today.

5.6 "To-Be" Equipment

The following section describes the equipment proposed for implementation in the FM & TS chassis and transformer areas. This equipment significantly improves the operations in these areas and provides for the operations of these areas on a higher level of automation with, in some cases, the upward compatibility to an advanced work center controller being considered for future implementation.

5.6.1 Chassis Area Equipment Improvements/Upgrades

There are a number of equipment improvements or upgrades that are presented in the "To-Be" operations in the chassis area. While these also improve processes and testing, they are presented in the following section because they are specifically equipment related. These improvements include:

- Specialized workstations
- Pneumatic powered torquing tools
- Machine Group equipment
- DITMCO fixturing upgrade

The following paragraphs describe each of these improvements in general. A more detailed description as well as the methodology and calculations used to arrive at the definition of these improvements and their justification is contained in Section 8.6 of this report.

Specialized Workstations

Upgrading the chassis area workstations (in conjunction with improvements in equipment used at these stations) provides significant improvements in the quality of work performed and has a measurable payback in the decrease of actual hours expended at these workstations.

Several ergonomic workstation designs for accommodating the operations performed as well as the equipment used for these operations were reviewed and the specifications as a result of this review are included in Section 9 of the Final Report.

Pneumatic Powered Torquing Tools

The goal in analyzing the applicability of pneumatic powered torquing tools to the operations performed in the chassis area was to develop an integrated approach to mechanical assembly within the area to replace the current manual/low power, screwdriver/nutdriver methods.

Realizing that torquing requirements for the range of fasteners used would require several tools, a search was conducted to locate a tool combination which would minimize the number of applicators and provide built-in torque control functions. With such a device, torque settings can be loaded manually from a control panel or from a communications link download (RS232C).

This makes the device's application ideal for future CIM implementation. The combination of a workstation controller linked to the tool allows the specifications for a particular fastener in a given application to be precisely tailored to the requirements of the task via the assembly part number and the specific layout operation. With a database containing the layout (with operation steps), tool type, and fastener, data can be stored in a look-up table and input upon request (via bar code or touchscreen data entry) to the torque controller.

Machine Group Equipment

The current chassis operations production flow involves transporting work to a remote machine group within the St. Louis Park facility. This remote area is located approximately 550 feet away and requires that material transport be performed by stores personnel. This transport as well as the non-dedicated processing and operations results in a turnaround time of 2 or more weeks. Consequently, additional material queue is built into leadtime calculations to support desired schedules.

The compensation for leadtime additionally results in stockpiling partially completed subassemblies with corresponding labor investment to guard against interruption in supply.

The location of orbital/radial fastener equipment in the chassis area allows a majority of machine group operations (riveting) to be performed within the chassis area. The addition of a small air-powered arbor press additionally permits staking and keying of wirewrap plates. Both pieces of equipment are quiet and do not contribute significantly to ambient noise level.

The major benefits of incorporating machine group operations into the chassis area are closer control of build schedule and process quality. In this regard, FM & TS's goal should be to bring as many of the operations within each process under direct control of the responsible area within FM & TS. This will ensure that the proper attention is focused on areas requiring improvement and resources can be appropriately applied.

Specifications for the proposed equipment are presented in Section 9 of this document.

DITMCO Fixturing Upgrade

A potential enhancement proposed for FM & TS Project 87 was the expansion of the DITMCO machine by adding an additional bay to allow higher volume chassis adapters to remain hooked up. It was thought that this would result in fewer problems with the interfacing cables and, consequently, reduce the time spent troubleshooting fixturing problems as opposed to the chassis under test.

Operationally, the proposal is attractive. However, equipment limitations may produce problems other than those proposed to be solved.

As an alternative, a fixturing scheme has been reviewed which involves a product plate and specialized interfaces for each chassis to be tested. This proposal makes the testing more automatic and additionally reduces operator exposure to the potential for "Carpal Tunnel Syndrome" by eliminating the need to seat adapter cards into the unit under test. This method will also accommodate future wired cage designs at nominal fixturing costs.

The alternative fixturing scheme appears to be the best solution to current situations.

5.6.2 Transformer Area Equipment Improvements/Upgrades

There are a number of equipment improvements or upgrades that are presented in the "To-Be" operations in the transformer area. While these also improve processes and testing, they are presented in the following section because they are specifically equipment related. These improvements include:

- Improved transformer ATE station
- Ink Jet marking
- Oven monitoring network

The following paragraphs describe each of these improvements in general. A more detailed description as well as the methodology and calculations used to arrive at the definition of these improvements and their justification is contained in Section 8.6 of this report.

Transformer ATE Station

Transformer testing in the "As-Is" process utilizes equipment which consists of several large consoles configured to test the more complex attributes of transformers in addition to various smaller testers used to check winding polarities, turns ratios, shorted turns, etc. This variety of manual transformer testers requires time-consuming setups and movement of parts from tester to tester depending on parameters measured.

The use of a state-of-the-art automatic tester will perform the necessary tests more quickly and eliminate the need for multiple set-ups. The tester recommended to achieve these improvements is an Optimized Devices model 80-T High Speed Linear Transformer Test System.

Ink Jet Marking

An alternative to the stamp application of ink is the use of non-contact, or ink jet, marking. This method is highly legible and will accurately mark irregular surfaces at high rates of speed. Ink jet equipment is manufactured by several vendors and typically a small system to mark approximately 0.1 inch high lettering costs in the range of $17,000-$23,000. This equipment utilizes ASCII coded data which could be sent from a PC or other equipment capable of generating the correct input.

Oven Monitoring Network

The oven monitoring network for implementation in the transformer epoxy area consists of a thermocouple installed in each oven, tied to a processing panel, and linked to an interface in a personal computer (which serves as the network monitor point).

The time and temperature limits for each transformer to be cured are loaded into the PC and then continuously monitored over the process time. The operator is warned audibly and/or visually if the correct temperature conditions are not maintained as well as at the end of each curing cycle.

SECTION 6

PROJECT ASSUMPTIONS

ITM Project 87 has proceeded with the following assumptions as fundamental guidelines. Project implementation could be impacted and schedules affected if alternative approaches or significant deviations to plan are executed.

- Capital funds will be available for equipment purchases during fiscal year 1988.
- Support personnel will be available to review and implement process documentation plans.
- FM & TS Production Engineering will coordinate implementation efforts.
- Production, Production Engineering, and Quality Assurance will develop and execute the required program changes to implement the quality control process changes.
- Each unique workstation will be configured and pilot testing will be completed prior to commencement of full scale production. This activity will occur within the respective area utilizing production operators.
- Implementation will not be considered finalized until designated equipment is in place as depicted in the ITM Project 87 plan.
- As much as practical, software packages procured as part of the project implementation will be standard, off-the-shelf products so as to avoid on-going maintenance associated with customized packages.
- For the project duration, the transformer build schedule is assumed to be flat while the chassis build is tied to revenue growth within FM & TS.

SECTION 7

GROUP TECHNOLOGY CODING SYSTEM ANALYSIS

The term Group Technology has been alternately used to describe either of the following:

1) a process of codifying parts in a computer database in order to group similar parts or,

2) the organization of product families into cells in order to eliminate the duplication of resources.

The first definition of Group Technology was developed during the 1970's for the standardization of production materials and is used in a number of ways in the design and manufacture of a wide variety of products. The major impetus for this came through the use of more powerful and sophisticated computer systems and integrated CAD design software.

The second definition presented above is a more recent view of Group Technology. This method has been adapted from the Japanese and provides a more global view of integrating manufacturing processes and streamlining production operations.

7.1 Tooling Requirements Coding System

A codifying of all parts used at Honeywell would be an extremely large undertaking and would require the coordination of several divisions to assure its effectiveness and to realize significant cost savings. While this would be an effective endeavor for Honeywell, this was not a reasonable task for the implementation of ITM Project 87. However, the project team developed matrices to define the specific hardware (i.e., fasteners, screws, nuts) used in the chassis and transformer areas as an aid in establishing proposed equipment and workstation requirements.

In this matrix all the Honeywell assembly and subassembly part numbers processed in the chassis area in 1986 were listed on the x axis, and each fastener called out in the production layouts for these products was listed on the y axis of the matrix. The number of specific fasteners used for each assembly or subassembly was then listed at the intersection point and that quantity was multiplied by the total production volume for the subassemblies or assemblies. This yielded the total quantity of each fastener used by the chassis group in 1986.

The fastener part numbers were then analyzed for tooling requirements for their application in the process. This was performed by reviewing each of the layouts for 1986 and 1987 production and noting the torquing requirements, fastener type, special attributes, and other factors. These factors were then clustered for similarity (i.e., Phillips head screws, etc.) and listed on a tooling requirements matrix. Applicable types of tooling were balanced against these factors to determine whether or not they could meet all of the production requirements.

7.2 Production Operations Grouping Matrix

The grouping of production operations was achieved by developing large scale matrices which correlated the Honeywell part number with the operations and the standard hours required to perform these operations. These correlation matrices provided important information for grouping similar processes at workstations, defining the equipment required at each specific type of workstation as well as the actual number of workstations required for each of these groupings of operations.

The process that was employed for grouping production operations is in some respects similar to that described in Section 7.1. The steps for developing this matrix were:

1) All part numbers of assemblies and subassemblies were listed along the "y" axis of the matrix.

2) Production layouts provided the operations descriptions (which are in the process of standardization and codifying) for each operation for the production of a sub-assembly or assembly. These operations descriptions were listed along the "x" axis of the matrix.

3) At each intersection in the matrix of a part number and an operation description, the standard hours for an operation for that part number were entered.

4) After the data was entered into the matrix, each individual production operation was analyzed for grouping at a specific type of workstation dependent upon the processes performed.

5) Similar processes or processes requiring the same type of tooling and equipment were grouped together.

6) The matrix was then condensed to define a set number of types of workstations that could facilitate the grouped operations.

7) On separate versions of the matrix, production totals (box and spares counts) were entered for the years 1986 and 1987. These were then multiplied for each part number and each operation column was totaled.

8) These standards were then verified for 1986 using the Foreman's Cost Report (for total hours expended in the operational area) as a check against the completeness of the matrix.

9) Business volume projections were established for the operational area (chassis, transformer) and standard hours were projected for ten years using an established percentage growth for the FM & TS operations.

10) Actual hours for each type of workstation were established using cost variance ratios established by FM & TS Cost Accounting department.

11) Actual number of workstations was established by dividing actual hours per type of workstation by 1800 hours. The assumption of 1800 hours/year/employee allows for 80 hours vacation, 80 hours holiday, 120 hours for lost time (sick, jury, etc.).

12) This established the number and type of workstations required for all current programs for the next ten years and provides a methodology for establishing the number and type of workstations required as newer programs are phased in.

7.3 Summary

Once all of the workstations were designed using the procedures outlined in Sections 7.1 and 7.2, the groupings of the workstations were laid out based upon the process flow to provide optimized routings for the majority (approximately 80%) of the product that will be built in the work area. In addition, the accessibility of resources was analyzed in relation to the work cell designs as well as the physical characteristics of the products assembled.

Following the development of the work cells, these were then laid out for optimum routing between each cell. Once the work area was designed, the material handling and storage requirements were developed to facilitate the process flow between cells.

SECTION 8

PRELIMINARY/FINAL DESIGN AND FINDINGS

The following section describes the process of preliminary findings and design iterations as well as the Final Design that will be in place as a direct result of ITM Project 87 and the final design findings that led up to it. In addition, several areas are described within the FM & TS chassis and transformer environments that, while not directly affected by the improvements incorporated for ITM Project 87, either provide the groundwork for the improvements developed or are tangentially affected by the efforts dedicated to ITM Project 87.

The primary emphasis of ITM Project 87 is on the improvement of processes and the upgrading of assembly and test equipment. Other areas described briefly in this section include:

- Production/Process Flow
- Material Flow
- Information Flow

8.1 "To-Be" Operations Overview

The approach to the development of the final design of the "To-Be" factory has been described in Section 3 "Technical Approach". In addition, in describing the "To-Be" factory in Section 5, the refined methods for arriving at the "To-Be" design are included as part of the justification and description of that design. In an effort to reduce the amount of "duplicated" data contained in the Project 87 Final Report, the following section describes in general the features of the preliminary/final design as it evolved.

8.2 "To-Be" Production/Process Flow

The "To-Be" production/process flow is presented in the following sections. One of the major improvements in the optimized design of the production/process flow for each of the areas is the development of a straightforward production flow that is aligned with the process flow. Additionally, in the transformer area, the consolidation of the geographically distinct operations will result in significant production flow improvements.

8.2.1 Chassis Area Production/Process Flow

The chassis area in the "To-Be" configuration integrates the sequential processes necessary to produce a finished chassis for the various models so that duplication of stations is unnecessary to ensure uninterrupted product flow.

Each wire wrap plate passes through a series of stations to and from wire wrap depending on the necessary preparation or post wrap work. Since no program volume is sufficient to fully utilize a given station (except wire wrap), the process orientation allows significant labor consolidation. Similarly, in chassis build-up, tooling and parts are centralized and material stocking can be concentrated in storage systems (e.g., VS/RS) to save transit, search, and picking times.

8.2.2 Transformer Area Production/Process Flow

A survey of the top eighty percent of transformer assemblies and subassemblies produced during 1986 was performed to establish the transport profile for the area and determine the resources required to move these parts through the production process.

The external movement analysis Summary of the transport between the respective operational areas consumed an estimated 1474 hours during 1986. This is important in two respects. The consolidation of the separate areas could potentially reduce the stockroom allocation to FM & TS. And, delays in processing and the effective application of FM & TS transformer personnel will be positively impacted as a result of maintaining uninterrupted production flow.

Intra-area movement provides minimal savings. This is a result of the relatively small number of transformer/subassembly lots processed. The comparison of flow distances within the "As-Is" and "To-Be" layouts resulted in a five percent transport reduction.

Additionally, the project team believes, and current industry experience bears out, that the combination of consolidating the respective transformer operations and developing ergonomic work cells will result in productivity gains in excess of ten percent per year.

8.2.3 Inspection Process Improvements

The advanced inspection strategy for implementation at Honeywell's FM & TS chassis and transformer area is detailed in a step-by-step procedure below.

Incorporation of an in-line Quality Control system coupled with savings due to elimination of time associated with transporting parts and/or waiting for inspection as well as start/stop losses and rework losses should more than offset inspection time added in the chassis process. Conservatively, time spent on inspection after 1988 should decrease from over 4% to under 2% of expended hours.

Present Total Quality Control theories maintain that "acceptance labor" should not exceed 1.8% of the total product if an enterprise is functioning "correctly". This means the process is under control and subject to constant measurement and improvement. If these criteria are applied to the chassis and transformer areas, the effect is a significant reduction in time spent "checking someone else's work". Everyone is a quality control person and responsible for driving defects out of the process.

This is not an overnight happening. Considerable planning, training, and commitment is required to accomplish (and sustain) results. In-process inspection is just one area which benefits from this approach. Essentially, it requires doing business in a much different way than in the past and a dedication of resources to the elimination of the causes of defects.

The program, as outlined below, is expected to take as much as a year to put in place, so no benefit is calculated until 1989. Resource expenditures for implementation are estimated at $60,000; $40,000 for training and $20,000 for product layout process modifications.

Listed here are some of the steps which will implement the revised quality approach:

Incorporation of In-Process Inspection

1) Review all production layouts with inspection requirement(s).

2) Make a list of all inspection points from layouts.

3) Establish mandatory requirements and limits (tolerances) for each inspection operation.

4) Review all pre-inspection operations for definitive quality criteria (appearance, limits, tolerances, values, etc.).

5) Develop checklist to cover all inspected-for criteria for each operation step in process.

6) Investigate special tools, stops, templates, etc. which will provide simple, straightforward self-checks of assembly quality.

7) Solicit input from area operators, technicians, group leaders, etc. on ways to improve the "process". Explain what is being tried, stressing job scope expansion and reliance on each worker's self-imposed efforts to do a quality job.

8) Provide training in "creative problem solving" to enable the group to collectively develop ideas to improve quality and incorporate self-inspection into the assembly and test process.

9) Implement a "pilot line" approach by starting with an individual assembly, then expand to all assemblies of a given type, then the next type, then finally to all assemblies. Be prepared to modify any

and all aspects of the implementation to accomplish the desired results.

10) Provide continual management/supervisory support for the program. Make sure progress is being made through periodic "sit downs" with the groups and/or leaders. Encourage participation by everyone. Stress the value of all ideas, whether used or not.

11) Maintain focus. The goal is to incorporate inspection into the process and accomplish that function at less cost than before. [Contrary to what might be expected, standard operation times will generally be no higher than before implementation started. This is because the quality (or inspection processing) is part of the process, not apart from it. Greater reliance on operator accomplishment and integrity coupled with appropriate training generally results in a superior product.]

8.3 "To-Be" Material Flow

The improvements in the "To-Be" material flow are presented in the following paragraphs. However, because the scope of consideration of material flow improvements is not addressed in the ITM Project 87 proposal (reference ITM Project 88), it is only discussed briefly here.

In general, a number of characteristics can be stated regarding the improvements in both the chassis and transformer areas. The most important improvements in the material handling for both of the areas involves the methods and equipment used for material and fixturing storage. In the "To-Be" operations, a majority of all of the material in these work areas will be stored in Vertical Storage and Retrieval Systems (VS/RS). This reduces the floor space utilized significantly and consolidates material into specific areas adjacent to the materials' points of use which reduces the material movement travel time.

Another significant improvement associated with the implementation of the VS/RS units is the purchase of a computer-driven material locating system for each of the VS/RS units in the areas. This will serve to eliminate excessive time required to search for the appropriate materials and result in more optimized utilization of the storage devices.

Other material storage and handling equipment will aid in optimizing the material flow in the chassis and transformer areas. These include workstation storage bins for small parts and miscellaneous equipment as well as dedicated work carts for transporting material. Dedicated work carts serve to restrict the amount of work-in-process stored on the shop floor because of the limited number of available carts and to identify work that should be processed immediately.

8.4 "To-Be" Information Flow

The most significant improvements in the chassis and transformer area information flow will be achieved with the introduction of the HMS/BOS system currently being modified for use at the St. Louis Park facility. While on a conceptual level this system performs all of the same processes as the GAPOS system, the increase in functionality is significant. Because the two systems are similar in the types of functions they will be performing and the final definition of the system has yet to be implemented, the focus of this section will be primarily on the introduction of the Factory Data Collection system and the improvements outlined in this report that can be even further upgraded due to their selection for interfacing with a work center controller.

The Factory Data Collection (FDC) system has been developed as a means of automatically recording hours an employee expends on a specific operation/part number. This provides important information to FM & TS management both for accounting purposes as well as monitoring the percentage of completion of a specific part being built. It is envisioned that in the future, the FDC system will be expanded to provide location tracking of work-in-process as well.

Improvements that have been included in this report that can be further upgraded for interfacing with a currently envisioned work center controller include:

- Pneumatically powered torquing tools. These tools have an RS-232 interface and torquing requirements can be downloaded from a higher level controller when a specific operation has been indicated as being performed. This indication could come through the bar code wanding of a production routing sheet or the on-line touchscreen interface request to perform an operation.

- Material Storage and Retrieval System. Location look-ups can be directed by a higher level controller based upon an operator's request for the next job to be processed.

- Oven Monitoring Network. Temperatures and cycle times can be downloaded from a centralized computer database for each part number to be cured.

- ATE. Transformer and Chassis area ATE equipment can be networked in the future in the same manner that the H2600's are networked in the current FM & TS Card and Device area.

- Other Equipment. It is conceivable that even the ink jet marking in the transformer area as well as the wire wrap machines in the chassis area could be interfaced to a work center controller for more complete control and monitoring of operations within the respective areas.

One other program which is currently under evaluation for Honeywell's MAvD is the introduction of a "factoryvision" system (ITM Project 32) which will present production layouts and other production related information to each of the operators on the shop floor. This type of system, interfaced with a work center controller would raise Honeywell's operations to the most advanced, state-of-the-art achievable with the computing technology available today.

8.5 "To-Be" Equipment

The following section describes the equipment proposed for implementation in the FM & TS chassis and transformer areas. This equipment significantly improves the operations in these areas and provides for the operations of these areas on a higher level of automation with, in some cases, the upward compatibility to an advanced work center controller being considered for future implementation.

8.5.1 Chassis Area Equipment Improvements/Upgrades

There are a number of equipment improvements or upgrades that are presented in the "To-Be" operations in the chassis area. While these also improve processes and testing, they are presented in the following section because they are specifically equipment related. These improvements include:

- Specialized workstations
- Pneumatic powered torquing tools
- Machine Group equipment
- DITMCO fixturing upgrade

The following paragraphs describe each of these improvements in detail as well as the methodology and calculations used to arrive at the definition of these improvements and their justification.

Specialized Workstations

Upgrading the chassis area workstations (in conjunction with improvements in equipment used at these stations) provides significant improvements in the quality of work performed and has a measurable payback in the decrease of actual hours expended at these workstations.

Several ergonomic workstation designs for accommodating the operations performed as well as the equipment used for these operations were reviewed and the specifications as a result of this review are included in Section 9 of this report.

The actual hours (used in determining the savings from the introduction of these workstations) were computed from the 1986 production base matrix extended by the chassis area standard-to-actual ratio. A study by the U.S. Navy

Electronics Manufacturing Production Facility (EMPF) determined that the productivity improvement resulting from the use of modular workstations was 22%.

This percentage improvement was then applied only to workstation related tasks in the chassis area (DITMCO and wire wrap hours were excluded). The percentage of total hours expended in the chassis area at the pre wire mechanical and electrical as well as the post wire mechanical and electrical workstations was 41%.

The 41% (representing the percentage of total actual hours) was then multiplied by the 22% savings determined by the U.S. Navy EMPF for a total area improvement of 9.1%. This figure was then adjusted by taking the total improvement in implementing the workstations and subtracting the total improvements associated with pneumatic powered torquing tools to provide a net total improvement lower than the 9.1% determined.

Pneumatic Powered Torquing Tools

Applicability of Pneumatic Powered Torquing Tools

The goal in analyzing the applicability of pneumatic powered torquing tools to the operations performed in the chassis area was to develop an integrated approach to mechanical assembly within the area to replace the current manual/low power, screwdriver/nutdriver methods.

Two basic systems for fastener application were reviewed as improvements over current methods. These were; (1) multiple pneumatic drivers for several fastener classes with station-resident, tool calibration facilities, and (2) minimal pneumatic drivers (1 or 2) for all fastener classes with transducer feedback and control of torque

Chassis area production layouts were analyzed for all operations where fasteners were used and provided the baseline data to create a part number/1986 hardware volume usage matrix. This matrix included threaded fasteners (nuts, bolts, screws) which could be inserted via nut or screw drivers, whether manual or powered. Annual quantities of threaded hardware were derived to facilitate economic evaluation of manual or powered driving.

Actual driving time for manually installing fasteners was determined to be 21 seconds. Pneumatic (or powered) application was determined to be 7 seconds. These values were derived from earlier investigations involving electro-mechanical assembly of chassis mounted parts as well as efforts by the Industrial Engineering group within Honeywell. A general rule is that pneumatic drivers can run threaded devices faster by a 3:1 ratio over manual means, which is born out by these investigations. Fastener handling time [pick and set] was determined as unchanged.

Utilizing the average manual application time of 21 seconds, this resulted in 506 standard hours for all fasteners used during 1986 while the automatic method was estimated to require 169 standard hours. Then, utilizing the existing chassis area standard-to-actual ratio, the "As-Is" actual hours condition was computed. Using FM & TS growth estimates, a projection of the actual hours using the existing method during the 1989 production year (the first full year of the use of any new methods) was established.

Using the 3:1 ratio for automatic methods results in a projected savings of over $15,000 in the first full year of utilization to perform the same tasks.

Tool Selection Considerations

Realizing that torquing requirements for the range of fasteners used would require several tools, a search was conducted to locate a tool combination which would minimize the number of applicators and provide built-in torque control functions. With such a device, torque settings can be loaded manually from a control panel or from a communications link download (RS232C).

This makes the device's application ideal for future CIM implementation. The combination of a workstation controller linked to the tool allows the specifications for a particular fastener in a given application to be precisely tailored to the requirements of the task via the assembly part number and the specific layout operation. With a database containing the layout (with operation steps), tool type, and fastener, data can be stored in a look-up table and input upon request (via bar code or touchscreen data entry) to the torque controller.

The multiple tool alternative described earlier, however, does not have the benefit of automatic or semi-automatic torque selection and control and was not considered as applicable for advanced manufacturing environments.

Payback Analysis

In the proposed chassis area floor plan, two areas are designated for the pre- and post- wire wrap mechanical assembly operations. Duplicate stations are proposed, eliminating spare parts requirements peculiar to either. With an allocation of $10,000 per station (including spare parts), payback is less than 1.5 years.

Machine Group Equipment

Routings associated with machine group functions were reviewed to determine the suitability of incorporating these operations into the chassis area operations flow as opposed to transporting work-in-process to a remote area.

The initial considerations were that lower standard hours could be developed for riveting and staking operations using powered equipment. Subsequent discussions with vendors and FM & TS personnel highlighted the main cost drivers to be leadtime reductions and improved quality of the finished product.

The current chassis operations production flow involves transporting work to a remote machine group within the St. Louis Park facility. This remote area is located approximately 550 feet away and requires that material transport be performed by stores personnel. This transport as well as the non-dedicated processing and operations results in a turnaround time of 2 or more weeks. Consequently, additional material queue is built into leadtime calculations to support desired schedules.

The compensation for leadtime additionally results in stockpiling partially completed subassemblies with corresponding labor investment to guard against interruption in supply.

The location of orbital/radial fastener equipment in the chassis area allows a majority of machine group operations (riveting) to be performed within the chassis area. The addition of a small air-powered arbor press additionally permits staking and keying of wirewrap plates. Both pieces of equipment are quiet and do not contribute significantly to ambient noise level.

With the assumption that an even distribution of hours are expended over a production year, a reduction of two weeks of labor results in a one-time labor savings during 1988. Some reduction in material carrying cost will also result, though it is not significant.

The major benefits of incorporating machine group operations into the chassis area are closer control of build schedule and process quality. In this regard, FM & TS's goal should be to bring as many of the operations within each process under direct control of the responsible area within FM & TS. This will ensure that the proper attention is focused on areas requiring improvement and resources can be appropriately applied.

Specifications for the proposed equipment are presented in Section 9 of this document.

DITMCO Fixturing Upgrade

A potential enhancement proposed for ITM Project 87 was the expansion of the DITMCO machine by adding an additional bay to allow higher volume chassis adapters to remain hooked up. It was thought that this would result in fewer problems with the interfacing cables and, consequently, reduce the time spent troubleshooting fixturing problems as opposed to the chassis under test.

Operationally, the proposal is attractive. However, equipment limitations may produce problems other than those proposed to be solved.

As an alternative, a fixturing scheme has been reviewed which involves a product plate and specialized interfaces for each chassis to be tested. This proposal makes the testing more automatic and additionally reduces operator exposure to the potential for "Carpal Tunnel Syndrome" by eliminating the need to seat adapter cards into the unit under test. This method will also accommodate future wired cage designs at nominal fixturing costs.

A comparison of the standard hours for DITMCO operations for the "As-Is" process vs. the estimated standards using the proposed fixturing scheme indicated a considerable savings potential. Using the present standard-to-actual hours ratio for DITMCO operations and a ratio estimated by Production Engineering for the new method a savings of over $28,000 is projected for 1989 (the first year of savings).

8.5.2 Transformer Area Equipment Improvements/Upgrades

There are a number of equipment improvements or upgrades that are presented in the "To-Be" operations in the transformer area. While these also improve processes and testing, they are presented in the following section because they are specifically equipment related. These improvements include:

- Improved transformer ATE station
- Ink Jet marking
- Oven monitoring network

The following paragraphs describe each of these improvements in detail as well as the methodology and calculations used to arrive at the definition of these improvements and their justification.

Transformer ATE Station

Transformer testing in the "As-Is" process utilizes equipment which consists of several large consoles configured to test the more complex attributes of transformers in addition to various smaller testers used to check winding polarities, turns ratios, shorted turns, etc. This variety of manual transformer testers requires time-consuming setups and movement of parts from tester to tester depending on parameters measured.

The matrix of transformers produced in 1986 was screened for standard test times to arrive at the total "As-Is" hours expended for testing during that period. Applying the area standard-to-actual ratio yielded a total of nearly 3,600 hours spent on testing (this compares favorably with the number of operators presently engaged in testing activities).

Because of the multiple setups at various test consoles required to functionally exercise the "typical" transformer, hook-up alone in the "As-Is" condition consumes nearly 2-1/2 minutes, while testing, recording, instrument adjustment, and sequencing take slightly less than 4 minutes. The use of a state-of-the-art automatic tester will perform the necessary tests more quickly and eliminate the need for multiple set-ups. Since the proposed testing scheme only requires one hook-up and no instrument adjustment or recording, significant savings is possible.

A review of the production layouts for the top eighty percent of tested transformers was conducted to determine the average (and median) number of leads on the "typical" transformer. This was also factored with the number of occurrences of testing (one, two, or three times) to arrive at a "weighted" average number of leads for a typical transformer.

This number was multiplied by an estimated time for connection, test, and disconnection (determined by Honeywell IE study) to arrive at a total test time of 58 seconds for the "typical" transformer using an ATE testing scheme (connect=38 seconds, test=10 seconds, disconnect=10 seconds). This figure was then applied to the 1986 testable build quantities to arrive at a comparison "To-Be" condition.

It is felt that since several multi-lead transformers will be tested by "plugging" into a socket fixture, a conservative approach was used by assuming that all transformers required manual lead connection. By applying the aforementioned ATE test times for ATE testing, extended by the total number of devices tested in 1986, the annual savings was projected to be $87,979 during 1989, the first full year of operation.

The tester recommended to achieve these improvements is an Optimized Devices model 80-T High Speed Linear Transformer Test System.

Ink Jet Marking

Typical transformer marking standards range from 32 seconds to 2.4 minutes per part with the greatest volume set at the lower standard. Actual practice, however, generally takes longer, since the application of part numbers to assemblies requires uniformity and legibility to satisfy quality standards. As described by production engineering personnel, this is not easily accomplished on many parts due to surface characteristics and the nature of the ink and application stamp.

Based upon information contained in Honeywell's "Labor Analysis Report - Computerized" (LARC) the actual time spent on the marking operation is approximately 2 minutes per transformer. This is based on the actual time spent in marking 310 transformers using the "As-Is" ink stamping method.

An alternative to the stamp application of ink is the use of non-contact, or ink jet, marking. This method is highly legible and will accurately mark irregular surfaces at high rates of speed. Ink jet equipment is manufactured by several vendors and typically a small system to mark approximately 0.1 inch high lettering costs in the range of $17,000-$23,000.

This equipment utilizes ASCII coded data which could be sent from a PC or other equipment capable of generating the correct input. Assuming that the 32 second standard is a realistic one using ink jet equipment, at current assembly rates over $6,000 per year can be saved with this equipment.

Oven Monitoring Network

The oven monitoring network for implementation in the transformer area consists of a thermocouple installed in each oven, tied to a processing panel, and linked to an interface in a personal computer (which serves as the network monitor point).

The time and temperature limits for each transformer to be cured are loaded into the PC and then continuously monitored over the process time. The operator is warned audibly and/or visually if the correct temperature conditions are not maintained as well as at the end of each curing cycle.

SECTION 9

SYSTEM/EQUIPMENT/MACHINING SPECIFICATIONS

The following sections present the detailed specifications that were developed as a result of the analysis and design performed for two areas within Honeywell's FM & TS operations under ITM Project 87. The first section provides system and equipment specifications for the Chassis area and the second section provides system and equipment specifications for the Transformer area.

9.1 Chassis Area Specifications

The chassis area specifications have been developed for specific types of workstations designed for the "To-Be" operations within FM & TS. Where a specific piece of equipment is required for more than one type of workstation, a reference is noted to review the specification presented for a previous workstation. To aid in analyzing the choice of equipment for these specific types of workstations, a short description of the operations performed at the workstation and an overview of the equipment required is presented.

In addition to this, specifications are presented for improved DITMCO test fixturing.

Workstation Equipment Specifications

Station: Pre-Wire Wrap Mechanical Assembly

Function: Operations primarily related to mechanically joining connector assemblies to fixtures prior to wire wrapping.

Equipment Requirements (per individual station):

1) One (1) torque regulated pneumatic driver with load balancer

2) One (1) torque tool test and control panel

3) One (1) Modular Work Bench

Pneumatic Driver Specification

Type:	Pistol grip or in-line, rear exhaust
Rotation characteristics:	Reversible
Starting Mechanism:	Trigger/lever or push to start (preferred)
Tool Head:	1/4" hex quick change chuck
Fastener Range:	6-32 to 1/4-20

Bit Range:	#1 through #3 Phillips, #4 through 1/4" slotted, 1/4" socket adapter
Torque Range:	12 inch-pounds to 60 inch-pounds
Torque Control:	Rotary strain gauge transducer
Load Balancer:	3 pound capability

Torque Tool Test and Control Monitor

Dimensions:	13 3/4" high x 15" wide x 6 3/8" deep, 17 3/4 pounds
Range:	0 - 200 inch-pounds
Accuracy:	± 0.2% full scale, ± 1 digit
Display:	4 digit alpha numeric, LED/LCD/Electro-luminescent for programming and torque values display. High/Low/Go lights for torque.
Programmability:	Lockable programming and 50 value memory with recall and rollover. Programmable timer and built-in system checks.
Communications:	RS-232C serial interface for data transfer
Power:	110 v AC, 50/60 Hz

Modular Work Bench

Dimensions:	72" long x 36" wide x 30" high. (Optionally, height may be variable but this requirement limits number of vendors).
Work Surface:	ESD controlled with grounding attachments.
Shelf space:	Adjustable footrest shelf. (This may negate the requirement for a variable height work surface).
	Metal Instrument Shelf with back panel for mounting color coded cups for fastening hardware. 15" deep x 72" long x 24" high.
	Load balancing bar mounted minimum 36" above worksurface.
Drawer space:	Four drawered unit with master-keyed lock that locks all drawers.
Electrical Requirements:	Duplex outlets (110 AC) with raceway (either mounted along work surface or shelf).

Pneumatic Requirements:	Minimum 3/4" air line with two outlets and standard quick-disconnect couplings.
Lighting:	Dual fluorescent tubes in overhead canopy with diffuser.

Station: Pre-Wire Wrap Electrical Assembly

Function: Operations primarily related to contact crimping and insertion plus hand wiring of base plate.

Equipment Requirements (per individual station):

1) Soldering station

2) One (1) Modular Workbench

Soldering Station

Station Characteristics:	Safety shield and support for soldering iron to avoid operator injury and "heat sinking" of tip
	ESD grounding point provided on case
	Tip wiping pad and storage pan provided
Tip Characteristics:	Tip temperature manually adjustable over range of 500 -
	Digital readout for tip temperature
	Soldering iron transformer isolated from AC source
	Tip fully grounded
	Tip leakage less than 0.5mV
	Tip temperature continuously monitored via thermocouple and automatically controlled within ± 10°F
Power:	115V 50/60 Hz
Wattage:	60W
Dimensions:	8" x 6" x 4"
Weight:	5 lbs.

Modular Work Bench

All specifications detailed in description of Pre-Wire Wrap Mechanical Assembly workstation description.

Station: Post Wire Wrap Mechanical Assembly

Function: Operations cover a wide variety of mechanical tasks including removing wire wrapped assemblies from fixtures and joining wire wrap assemblies with chassis components.

Equipment Requirements (per individual station):

1) One (1) torque regulated pneumatic driver with load balancer

2) One (1) torque tool test and control panel

3) One (1) Modular Work Bench

Specifications

All specifications detailed in description of Pre-Wire Wrap Mechanical Assembly workstation description.

Station: Post Wire Wrap Electrical Assembly

Function: Operations primarily related to wire routing and attachment and soldering after wire wrap operations are complete.

Equipment Requirements (per individual station):

1) Soldering station

2) One (1) Modular Work Bench

Specifications

All specifications detailed in description of Pre-Wire Wrap Electrical Assembly workstation description.

Station: Machine Group

Function: Operations primarily include riveting, swaging, and pinning of metal parts for use in chassis area.

Equipment Requirements (per individual station):

1) Radial/Orbital bench top riveter for joining parts

2) Pneumatically assisted arbor for pressing inserts, clinch nuts, etc.

3) One (1) Modular Work Bench

Orbital/Radial Fastening Equipment Specification

Power:	120V/60Hz
Air:	70-90 PSI
Mounting:	Benchtop
Capacity:	.020" - .250" diameter
Stroke:	.2" - 1.2" (continuously variable)
Fastener Types:	MS20426 Rivet - .93 diameter MS20470 Rivet - .062 diameter Threaded insert - .125 diameter
Tooling:	Up to ten (10) applicators to install rivets, swage terminals, and fasteners
Speed (Timing):	Minimum of .2 seconds (continuously variable)
Accessories:	Footswitch Guard Worklight

Pneumatically Assisted Arbor Specification

Press Capacity:	2,000 pounds
Pressure Control:	Air pressure regulation
Air supply:	110 PSI
Ram diameter:	1"
Stroke:	2"
Throat depth:	6" (min.)

Modular Work Bench

All specifications detailed in description of Pre-Wire Wrap Mechanical Assembly workstation description.

Additional Equipment Specifications

DITMCO Test Fixturing Specification

Master Fixture:	4096 points capacity
	Cable interface with DITMCO tester
	All cylinder fixture with min. 1050 pounds actuation force
	Product locater and UUT removable via drawer
	Maximum unit capacity 20' x 24" x 10" (depth x length x
	Product test fixture removable
Product Fixture:	Interface to master fixture
	Maximum 4096 contacts
	Spring loaded pins interface with UUT connector wire wrap
	Fixture dimensions approximately 36" x 30" x 3" (d x l x h)

9.2 Transformer Area Specifications

The transformer area specifications have been developed for the "To-Be" operations within FM & TS.

Transformer Marking Equipment Specification

Cabinet Dimensions:	31" high x 18" wide x 17" deep
Printhead Dimensions:	8 3/4" high x 2" wide x 2" deep
Weight:	110 lbs.
Print Speed (characters per second):	1185
Message Length (characters):	250
Character Size (mm) Standard:	2-5
Microprint size (mm):	1.2 - 2.4
Data Input:	RS 232 Interface (20mA Current loop optional)

Transformer ATE Specification

System Requirements:	IBM PC, 256K memory, two (2) floppy drives, optically coupled I/O

System Capabilities:	Winding voltage polarity + or - .25%	
	Winding voltage ratios	
	Winding DC resistance + or - .3%	
	Excitation current + or - .3%	
	Saturation current + or - .3%	
	Cure loss + or - .5%	
	Inductance + or - .5%	
	Capacitance + or - 1%	
	Impedance + or - .3%	
	Insulation resistance + or - 2 %	
	Hi Pot breakdown + or - 3%	
System Options:	Voltage/current bandwidth:	99KHz
	Excitation power:	400 VA (8A)
	Interconnection terminals:	26
	Inductance (incremental):	20A @ 5V
	Low resistance:	.001 ~.001 + or - .8%
	Printer (with data log software)	
Special Requirements:	Dielectric breakdown	
	500V/sec ramp and .35 sec ramp	
	Insulation resistance	
	Applied voltages: 100, 200, 250, 300, 500, variable to 1,000 VDC	
	Induced voltage:	750V @ 1200Hz
	Capacitance:	10 pfd lower spec limit
Center tap error:	1 MV lower spec limit	
	Safety cover interlock	
	Software modifications:	part number field length 3 space lead call-out on menu
	3-1/2" disk drive	

Oven Monitor Network Specification

Network Characteristics:	Sixteen channel (min.) temperature feedback to PC compatible interface
	Software monitor of temperature level with alarm for out-of-limits conditions
	System notification of cure time by alarm or programmable logic output and monitor display
Network Monitor:	IBM PC or PC compatible with min. 256K memory
	One (1) floppy disk
	Monochrome monitor
	20 MB hard disk (optional)
	Line printer (optional)
Thermocouple characteristics:	Resistance temperature detector (RTD) or thermocouple
	Range: 85°F - 300° F
	Max wire run: 50 feet
	Quantity: One (1) per oven monitored

SECTION 10

TOOLING SPECIFICATIONS

The following section describes the tooling required for ITM Project 87. Alternatives to the tooling descriptions in this section are presented in Section 12 - Equipment/Machinery Alternatives.

10.1 Transformer Marking

Generally, transformers requiring part number identification have this identification applied by way of a stamp and ink routine which has inconsistent results, requiring removal and re-application of the appropriate marking until legible characters are affixed to the part.

The proposed equipment provides a standard means of number application, consistent with the specification, so that repeated removal and re-application is unnecessary to obtain a legible, uniformly applied part identification. This system (from Domino Amjet, Inc.) will require no additional fixturing to achieve these results. However, if the proposed equipment becomes unavailable for any reason another approach will be necessary.

The following paragraphs describe the tooling which will be necessary if an ink-jet system that does not utilize a manufacturer supplied part carriage plate is purchased. To achieve the legibility and uniformity desired a combination of equipment and tooling is required.

The set-up consists of an ink jet printing head and control unit (specified in Section 5.6) combined with a fixture to hold the part to be marked. The fixture performs two functions:

1) Holds the selected part at the correct distance and at the proper orientation,

2) Moves the part relative to the ink jet head at the correct rate to effect uniform, legible printing.

The ink jet unit is an electronically controlled printing unit which applies a precisely measured amount of marking ink in a dot matrix pattern to identify a particular part with a set of selected characters.

The ink jet transformer holding fixture (shown in Figure 10.1-1) is a servo motor driven carriage plate mounted on a low friction ball slide riding across a tooled surface.

The plate is connected to a DC servo drive motor by way of a cogged drive belt and pulley. An input signal to the servo motor causes the carriage plate to traverse the fixture passing under the ink jet printing head. By

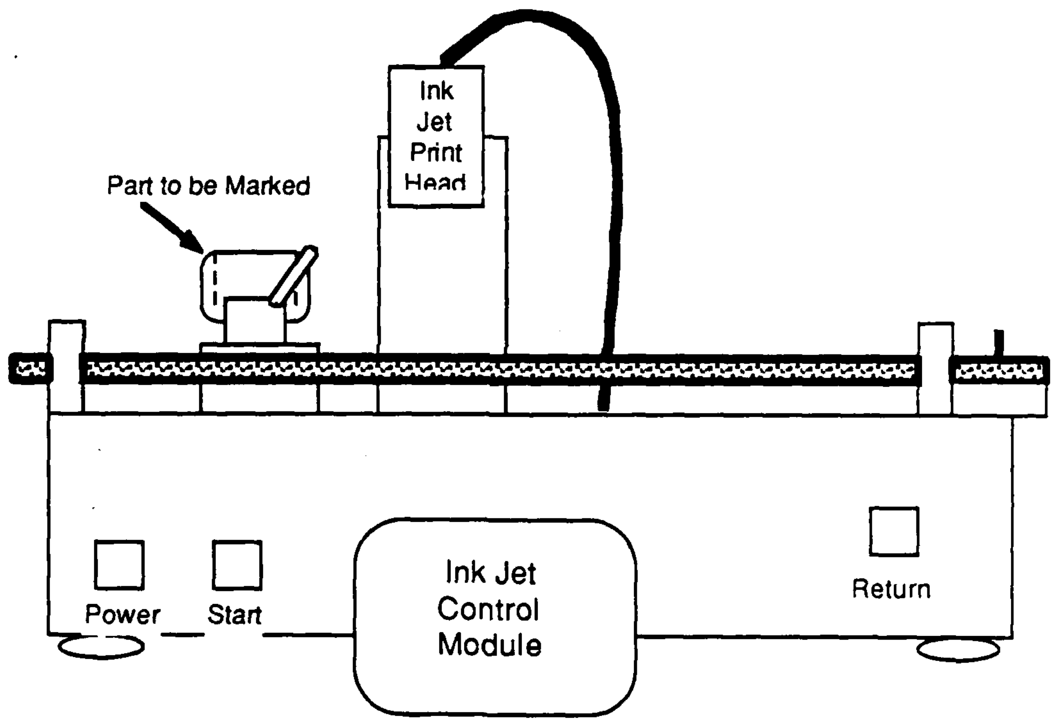


Figure 10.1-1 Typical Marking Setup

minimizing play in the various mechanical parts, repeatable results can be obtained, eliminating rework. A block diagram of the transformer marking system is shown in Figure 10.1-2.

Description of Operation

1.0) Part is clamped in fixture with proper orientation to printing head.

1.1) Test tape is affixed to part for verification run.

2.0) Power is applied to fixture

2.1) Electronics reset and positions carriage to home location

3.0) "START" button is depressed.

3.1) Signal "arms" printing unit.

4.0) Carriage, with transformer clamped in place, traverses fixture, passing under ink jet printing head.

4.1) Detector senses position of carriage and energizes printing operation.

5.0) Mount proceeds to opposite end of travel and stops.

5.1) Detector signals carriage "end of travel"

6.0) Marked transformer is removed from clamp.

7.0) "Return" button is depressed and mount returns to starting point on fixture.

8.0) Return to step 1.0 until lot is marked.

9.0) Remove power from fixture.

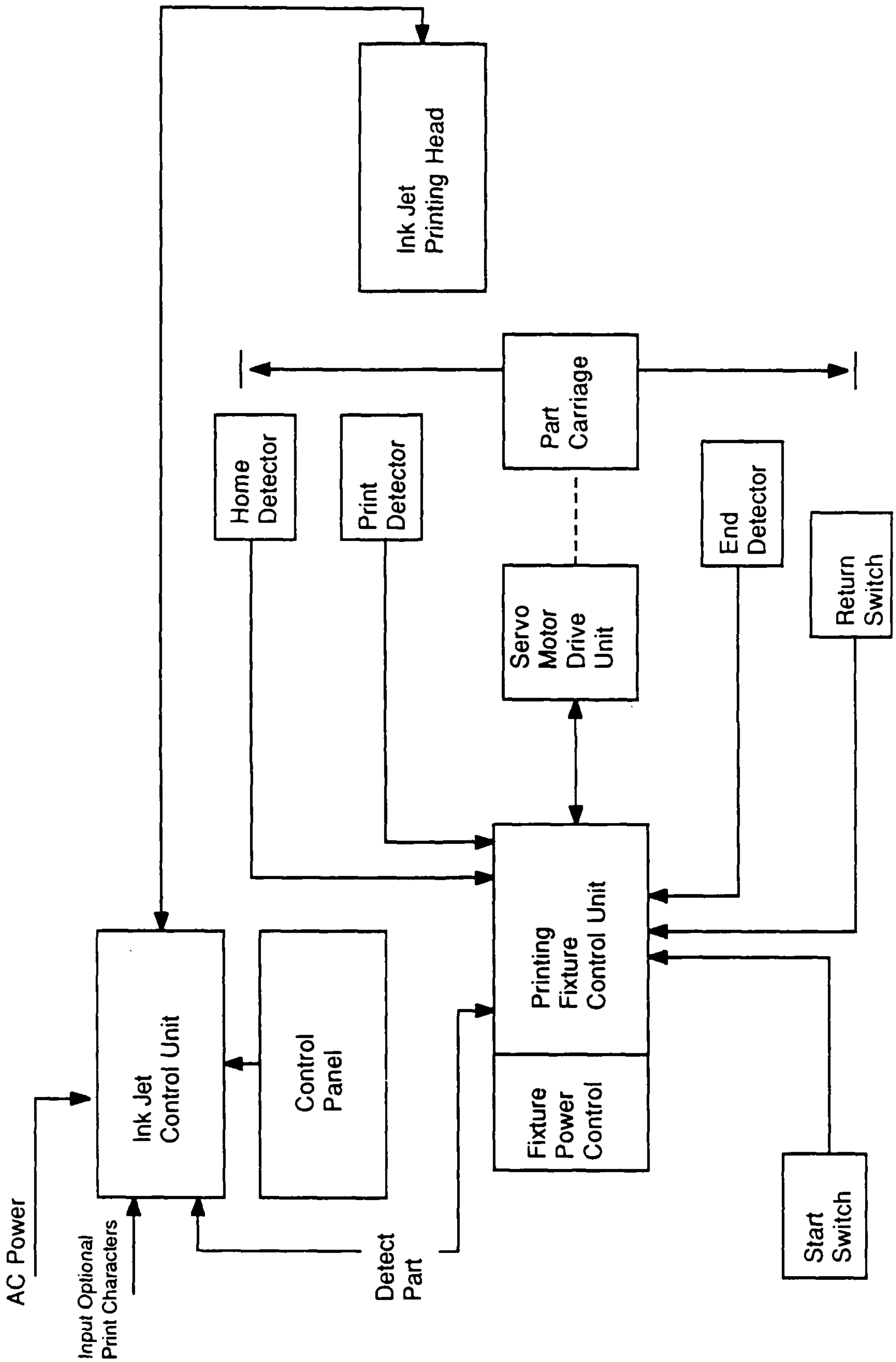


Figure 10.1-2 Transformer Marking System - Block Diagram

SECTION 11

VENDOR/INDUSTRY ANALYSIS/FINDINGS

The project objectives which dictated realistic cost-payback relationships ultimately caused the review of a condensed group of equipment/process upgrades. Some equipment had been previously reviewed by FM & TS personnel so that the preliminary search and selection process was bypassed in the interest of eliminating duplication of effort.

Since the ITM Project 87 review of the chassis and transformer areas centered on process improvements and equipment upgrades, the selection process focused on the following areas:

- Modular Workstations
- Power Assisted Tools
- Riveting/Staking Equipment
- Temperature Monitoring Networks
- Marking Equipment
- Computer Assisted Testing Equipment

Workstations

Known vendors such as Herman Miller, Straether, Advance, Ergotech, etc. provide a wide range of competitively priced equipment. Some vendors have unique features, which in specialized applications might dictate selection, but the stations proposed for Project 87 are readily available in a configuration meeting the current area specifications. Since a few workstations have been purchased within the past year (not as a part of this project) from Herman Miller to be used within FM&TS, it was decided to specify Herman Miller equipment for continuity of style unless a strong case can be made for a special application prior to implementation. As a result, the average cost of the previously purchased stations was used for computation of factory costs.

Power Assisted Tools

A key objective in increasing chassis area productivity was upgrading the tooling used in mechanical assembly. The search for equipment focused on pneumatically assisted screw and nut drivers which were suitable to apply the variety of hardware employed in the various chassis.

Initially, the investigation dealt with torque settable tools and a torque testing panel to validate tool settings. While this approach ensured accurate application of fasteners, changing torque settings for a multitude of fasteners would defeat a significant aspect of the savings these tools were intended to produce. An alternative, albeit costly, was to procure multiple tools to accommodate groups of fasteners. Since this approach was not cost effective due to the relatively low volumes produced, a search was conducted for an alternative.

The resulting survey uncovered a tool which utilizes a transducer to continuously feedback torquing information to a module which controls the tool pneumatic supply, thereby applying the correct torque for each application. The control module allows pre-set torque limits from a selected menu, so individual fasteners can be applied appropriately by entering a selection prior to operating the tool. In addition, this equipment allows torque data input via an RS-232 link, so process control can ultimately be established from a workstation controller. At present only one manufacturer produces this type of system: Stanley Tools, Cleveland, Ohio.

Riveting/Staking Equipment

A significant aspect in chassis leadtime is the out-of-area work, primarily accomplished in the Machine Group. These activities are primarily associated with riveting and staking, processes that can be performed by a wide variety of equipment.

The investigation of this class of equipment centered on units which could be located in the chassis area, thereby avoiding the delays associated with outside processing and would also produce consistent quality results without resorting to extensive training or operator experience. The equipment best suited to these requirements falls in a class of machinery known as orbital (or radial) riveters.

These units cause a progressive "flare" of a rivet or other malleable fastener by a rotary "peening" action as opposed to the compressive forces employed in a regular riveting machine. The result is a smoother, higher quality headforming action, free of stress cracks and bowing associated with compression riveters. A further advantage to orbital riveters is size. A unit which can adequately perform the required chassis area operations fits on a bench top and requires minimal utilities.

Several manufacturers produce equipment of this type, capacity, and within a competitive price range. The selection should be tied to the vendor who can best supply the necessary applicator tooling required to be used in the chassis assembly process.

Among the manufacturers supplying this equipment are: VSI Automation Assembly, Troy, Michigan; Bracker Corporation, Pittsburgh, Pennsylvania; Taumel Assembly Systems, Patterson, New York; and Raymark Formed Products, Milford, Connecticut. Based on quotations received and response to requirements two possible vendors were identified: Taumel and Bracker. The quoted prices for similar equipment were comparable with the Taumel machine slightly lower. Unless further information arises prior to implementation, a Taumel Model T-250 will be chosen for this application.

In addition to the equipment described above, a standard Arbor press will be required for certain applications. Response to requests for quotation was limited with only two vendors: Dake and BTM. The bid from BTM, Corp. was much more responsive to the requirements and is therefore the choice for this equipment at present. Because of the limited response additional vendor searches may be performed prior to implementation.

Oven Monitor Network

The upgrade of processes in the epoxy room centered on controls since oven replacement was felt to not be cost effective and unsuitable. Processing ovens generally are better suited to large batching or continuous processing. The review of transformer impregnation, coating, and curing specifications revealed a wide variety of time and temperature settings more conducive to a number of small ovens as presently utilized.

A monitor network provides continuous feedback to the epoxy room personnel so that periodic checking of ovens is unnecessary. The inclusion of a time alarm allows operators to concentrate on other tasks, only stopping to respond to the end of a curing operation. In selecting monitor equipment, it was felt a PC-based system with software and hardware integration was the preferred approach. Several manufacturers offer PC compatible systems, but the package felt to be the most adaptable without software modifications and scaled to be reasonably priced for the application is produced by Cyborg Corporation, Newton, Massachusetts.

Transformer Marking Equipment

Considerable effort has been expended by Production Engineering to locate a means to mark transformers in a manner consistent with existing specifications. The most recent investigation has centered on inkjet marking equipment because of its ability to apply highly legible identification on irregular surfaces.

The project team expanded this investigation to include additional vendors supplying suitable equipment for this application. A key factor is marking durability which is related to surface factors, ink solubility, adhesion, resistance to abrasion, etc. While additional experimentation remains, the project team is confident the inkjet approach satisfies the legibility issue which has been a source of on-going rework in the transformer area.

There are several manufacturers providing equipment to the packaging industry which is suitable for this application. The project team was able to review several products at the 1987 WESTPACK show in Anaheim. Among them are: Domino Amjet, Waukegan, Illinois; Marsh Company, Belleville, Illinois; Dennison Industrial Systems, Cedar Grove, New Jersey, and Videojet Systems, Elk Grove Village, Illinois.

The responses from Videojet and Domino Amjet were technically superior, with the Domino Amjet unit much more attractive because of the availability of a part carriage plate from the vendor. Therefore, a Domino Amjet Solo 4 system with a parts carriage plate was chosen for this application.

Transformer ATE

Existing product testing activities within the transformer area require the use of multiple testers to establish parts compliance with various parameters. Computer controlled equipment that requires one hook-up versus the multiple applications currently employed has been under review for some time. Currently available systems have an additional benefit of being controlled by PC based equipment. This provides wide program compatibility with an installed equipment base.

FM & TS Production Engineering has specified a unit which will test virtually all magnetics produced in the transformer area. The present approach will utilize the existing manual equipment as back-up until all programs are on-line and the tester has established suitable reliability. This will provide continued production capability and allow program testing and debugging.

The need for such a tester was identified vary early in the Phase 1 activity of the ITM program. Therefore, Production Engineering began an immediate search for a possible vendor. Since the testing activity is a specialized application, only one manufacturer could provide a suitable hardware and software package, fully adaptable to the transformer area requirements: Optimized Devices, Inc., Pleasantville, New York (model 80-T High Speed Linear Transformer Test System). As a result of the identification of the need for this tester and in view of the long leadtime for this equipment, the tester was ordered in November, 1986.

SECTION 12

EQUIPMENT/MACHINERY ALTERNATIVES

Most of the equipment alternatives in ITM Project 87 are vendor-dependent rather than actual alternative technologies. The following paragraphs describe the alternatives to the equipments selected for ITM Project 87 in the event that the primary choice becomes unavailable.

Workstations

The workstation vendor chosen (Herman Miller) is one of many which meet the requirements. There are several vendors whose equipment is comparably priced. Therefore, making use of one or more of the alternate vendors would have little or no impact on the project implementation.

Pneumatic Powered Torquing Tools

In the event that the Stanley Tools pneumatic torque feedback tool is not available, the present methods of fastener assembly would be continued. This would mean that the savings predicted from the use of the powered tools would not be realized.

Riveting/Staking Equipment

An alternative to the Taumel orbital headforming unit specified would be a similar machine from Bracker Corporation. The Bracker equipment represents an increase in price of approximately 10% over the Taumel unit. This is not considered a significant difference ($525) and should not adversely effect the overall savings of Project 87.

The choice of the BTM Corp. arbor press was as much a result of the lack of response to the request for quotation as any other factor. A survey of equipment available in trade publications reveals that there are many potential vendors of this type of pneumatic press. The project team is certain that another vendor could be found and that the price of the equipment ($3000 - $4000) is not a significant factor in the savings calculations.

Oven Monitor Network

No reasonable alternative to the Cyborg monitoring network has been found. In the event that it is not available. further searches would be performed. If no comparable system were found, the present method of manual monitoring and data recording would be continued.

Transformer Marking Equipment

If the Domino Amjet marking equipment is not available, the alternative would be a system by Video Jet which is basically similar in operation except that it would require additional tooling (as described in Section 10 of this report). This would result in a system which costs approximately $3000 to $4000 more than the recommended equipment.

Transformer ATE

The transformer ATE equipment is presently on order with delivery expected in the second quarter of 1988. Therefore, alternative equipment is not a consideration.

SECTION 13

MIS REQUIREMENTS/IMPROVEMENTS

The most significant improvements in the chassis and transformer area in respect to the Honeywell MIS department will be achieved with the introduction of the HMS/BOS system currently being modified for use at the St. Louis Park facility. HMS is a modular system comprised of the following modules:

- Master Production Scheduling (MPS)
- Inventory Records Management (IRM)
- Manufacturing Data Control (MDC)
- Material Requirements Planning (MRP)
- Capacity Requirements Planning (CRP)
- Purchase Material Control (PMC)
- Production Cost Accounting (PCA)

In addition to HMS, Honeywell is also implementing a process layout system which includes the Process Management System (PMS) and the Factory Data Collection (FDC) System.

The Factory Data Collection (FDC) system has been developed as a means of automatically recording hours an employee expends on a specific operation/part number. This provides important information to FM & TS management both for accounting purposes as well as monitoring the percentage of completion of a specific part being built. It is envisioned that in the future, the FDC system will be expanded to provide input to a system for location tracking of work-in-process as well.

Honeywell is also developing the specifications for a Work Center Manager System (WCM). While these specifications are still in the development phase, the improvements described in this document take into account the eventual implementation of these efforts and have been designed for future interface to a Work Center Manager System. The following paragraphs describe the basic functionality required of the Work Center Manager System.

A Work Center Manager System is typically a major piece of a hierarchically structured computerized factory control system. Residing at a higher hierarchical level than the WCM are the corporate systems and the MRP and MRP II systems such as HMS/BOS. Because MRP II systems are batch processing operations, the Work Center Manager has been assigned the responsibilities of direct, real time control of the factory floor. In this role, the system is responsible for short term, global scheduling tasks (during the operating day) and coordinating the inter-cell operations (such as material handling "hand-offs") that reside below it in the controls hierarchy.

It is also envisioned that the Work Center Manager will distribute graphics and textual process data to workstations and will maintain a process data library which will be accessed by various pieces of the process control hierarchy (such as PLC's and other automated equipment).

Improvements that have been included in this report that can be further upgraded for interfacing with a currently envisioned work center manager include:

- Pneumatically powered torquing tools. These tools have an RS-232 interface and torquing requirements can be downloaded from a higher level controller when a specific operation has been indicated as being performed. This indication could come through the bar code wanding of a production routing sheet or the on-line touchscreen interface request to perform an operation.

- Oven Monitoring Network. Temperatures and cycle times can be downloaded from a centralized computer database for each part number to be cured.

- ATE. Transformer and Chassis area ATE equipment can be networked in the future in the same manner that the Honeywell ATE testers are networked in the current FM & TS Card and Device area.

- Other Equipment. It is conceivable that even the ink jet marking in the transformer area as well as the wire wrap machines in the chassis area could be interfaced to a work center controller for more complete control and monitoring of operations within the respective areas.

One other program which is currently under evaluation for Honeywell's MAvD in conjunction with the Work Center Manager System is the introduction of ITM Project 32, which will present production layouts and other production related information to each of the operators on the shop floor. This type of system, interfaced with the Work Center Manager System would raise Honeywell's operations to the most advanced, state-of-the-art achievable with the computing technology available today.

SECTION 14

COST BENEFIT ANALYSIS AND PROCEDURE

In analyzing ITM Project 87, attention was focused on the methods and processes utilized in the FM & TS chassis and transformer areas. Activities reviewed in the transformer area included winding, leadset, testing, impregnating, and marking. In the chassis area, operations studied included machine operations, mechanical assembly, electrical assembly, wire wrapping, and continuity testing (DITMCO).

In the initial stages of the project, several areas were identified as cost drivers and reviewed for possible savings using the methodology shown in the process diagram of Figure 14.0-1. This also required the identification of productivity and quality factors as a means of evaluating the cost drivers.

14.1 Productivity and Quality Factors

The productivity and quality factors that exhibited the greatest potential for benefit were:

- Standard Hours (methods improvement)
- Actual Hours (productivity)
- *Inspection labor*

Factors identified from the contract ledger data and foreman's cost control reports which did not result in significant benefit were:

- Scrap
- Rework

Because of the diversity of product and/or the low annual volume levels, both rework and scrap were considered to be at relatively low levels in the ITM Project 87 areas.

The following paragraphs describe the major productivity and quality factors in the transformer and chassis areas for ITM Project 87.

Standard Hours

Product standard hours were derived from internal Honeywell documentation and extended for 1986 production volumes to establish "As-Is" conditions. These totals were compared to those logged in the Foreman's Cost Control report for 1986 as a validation measure.

Specific operation measurements were performed by Industrial Engineering to form a baseline for "To-Be" operations in transformer testing as well as establishing "As-Is" times for existing marking operations.

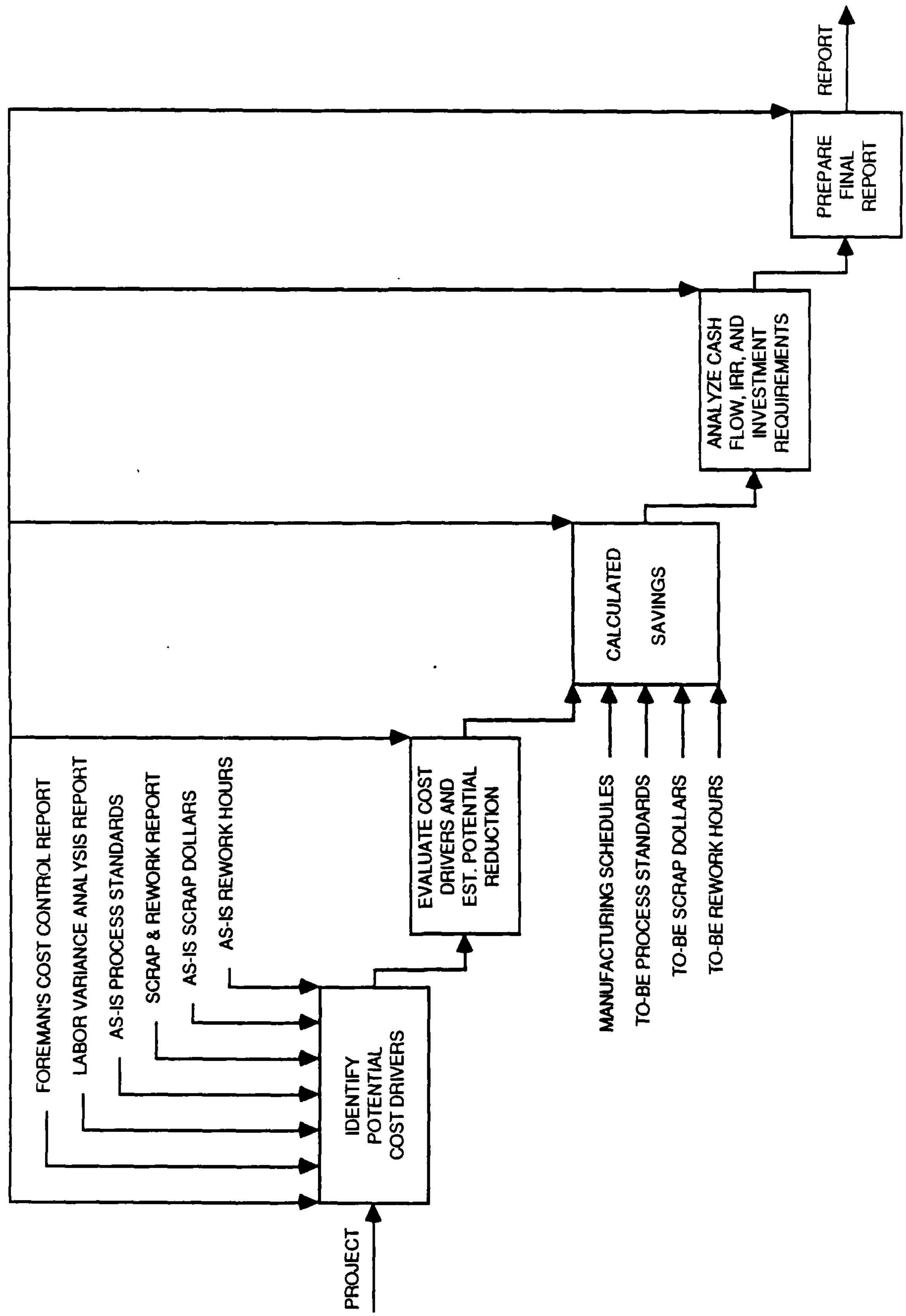


Figure 14.0-1 Cost Benefit Analysis Methodology

Estimates of most "To-Be" operational standards were derived from study data gathered by the project team. Specifically, time ratios utilized in establishing pneumatic tool savings were derived from an automation study concluded in 1986 by a major electronics manufacturer.

Evaluation of savings utilizing modular workstations, organized for specific functions in regard to tooling, was supported by data obtained in a study performed by the U.S. Navy Electronic Manufacturing Production Facility (EMPF), China Lake, CA and generally substantiated by productivity increases experienced in the electronics industry.

Actual Hours

In determining savings for the chassis and transformer areas, actual operating ratios derived from Foreman's Cost Control reports were utilized. All standard hours were "normalized" to actual hours to perform "As-Is" versus "To-Be" comparisons on an area-by-area basis. This method is then able to take into account all operational factors not normally included in standards.

Inspection Costs

In conjunction with modifications to the chassis and transformer work areas, inspection costs were reviewed and program changes were proposed to incorporate those activities into the manufacturing process. Incorporation of an in-line Quality Control system coupled with savings due to elimination of time associated with transporting parts and/or waiting for inspection as well as start/stop losses and rework losses should more than offset inspection time added in the process. Conservatively, it is estimated that time spent on inspection after 1988 should decrease from over 4% to under 2% of expended hours. It was also assumed that implementation would not occur until the first quarter of 1989, thereby allowing all of 1988 for process review and alteration as well as operator training.

Assumptions

All calculations are tabulated for ten yearly periods by quarter, beginning with the implementation point. Generally, implementation commences during 1988, with the modified inspection program being the exception as noted above.

Production rate increase/decreases are calculated based on the ten year marketing forecast for FM & TS revenue projected from factory production. This approach removes sources of revenue not directly attributable to products manufactured in the FM & TS production facilities addressed in the ITM Project 87.

14.2 ITM Project 87 Cost Drivers

The following areas that were identified as cost drivers and were reviewed for savings included:

- Chassis Power Tools
- Chassis Workstation Labor Savings
- DITMCO Fixturing
- Chassis Area Inspection Savings
- Transformer ATE Savings
- Transformer Marking Savings
- Transformer Area Inspection Savings

Chassis Power Tools Savings

The "As-Is" hours were based on the annual usage of 86,675 fasteners with an average application time (pick-place-drive) of 21 seconds as standard. The "To-Be" hours were based on the same annual usage and an average application time (pick-place-drive) of seven seconds as standard. Standards utilized from averaged data were derived from a survey of power tool versus hand tool applications. The hours represent actuals derived from standard data multiplied by the standard-to-actuals ratio experience in the chassis area.

Chassis Workstation Labor Savings

The "As-Is" condition was based on the annual actual hours expended in the chassis area as derived from the activities matrix standard hours and extended by the chassis area experienced standard-to-actual ratio. The "To-Be" reduction in annual hours is based on the percentage of total chassis area hours extended by the percent in productivity increase noted in the EMPF workstation study indicated in Paragraph 14.1.

DITMCO Fixturing

The "As-Is" condition was derived using the total annual actual hours expended in the DITMCO area on chassis undergoing continuity testing. The "To-Be" condition was derived using the total annual estimated actual hours to be expended as a result of fixture implementation.

Chassis Area Inspection Savings

The "As-Is" total hours were recorded as logged in the contract ledger by the inspection group during 1986 in support of chassis area activities. The "To-Be" total hours were estimated on the basis of an inspection program which results in actual inspection hours becoming a maximum of a pre-determined percentage of chassis area actual hours expenditure per year.

The percentage escalation in annual hours for the chassis area was derived from 1986 actual hours data multiplied by the estimated annual growth in FM & TS revenue (1987-1998). Hourly rates, burden, and escalation rates were obtained from Honeywell's Cost Estimating department .

Transformer ATE Savings

The "As-Is" condition total hours were derived from a matrix of part numbers produced in 1986 multiplied by the quantity of transformers tested and standard times plus "J" operations (sample testing) from the Foreman's Cost Control Data which was factored by the transformer area standard-to-actual ratio. The "To-Be" total hours were derived from a Honeywell Industrial Engineering department sampling survey of hook-up and tear-down times of 3.8 and 1.0 seconds per lead respectively, plus a ten second testing time.

Typical time in the "To-Be" condition for testing utilizes a ten lead transformer (median for 1986 build) with a 58 second standard (38 seconds hook-up, 10 seconds for test, and 10 seconds for tear-down) multiplied by the 1986 quantity and transformer area standard-to-actual ratio.

Transformer Marking Savings

The "As-Is" condition was derived using the total hours based on an estimate of the excess standard time expended multiplied by the 1986 build quantity and the transformer area standard-to-actual ratio (tested 11/87 on a limited sample). The "To-Be" condition was derived using the total hours based on improved methods achieving established standards multiplied by the 1986 build quantity and the transformer area standard-to-actual ratio.

Transformer Area Inspection Savings

The "As-Is" condition was derived using the total hours logged in the Contract Ledger by inspection personnel during 1986 in support of transformer area activities. The "To-Be" total hours were estimated on the basis of an inspection program which results in actual inspection hours becoming a maximum of a pre-determined percentage of transformer area actual hours expenditure per year.

No percentage escalation in transformer annual hours is included due to a management operational decision for the area dictating an essentially level build schedule. Hourly rates, burden, and escalation rates were obtained from Honeywell's Cost Estimating department .

14.3 Capital and Expense

The capital, recurring and non-recurring expenses for Project 87 are shown in Figure 14.3-1.

14.4 Project Savings and Cash Flows

The savings to be realized in this project exceeds Honeywell's Military Avionics Division hurdle rate.The project cash flows are shown in Figure 14.4-1 with the assumption that capital is available per the implementation plan.

PROJECT 87 EXPENDITURE SUMMARY

	GROSS COST	CAPITALIZATION YEAR
CAPITAL COSTS		
MACHINERY COST		
POWER TOOLS	$23,180	1988
RIVETER	$6,606	1988
ARBOR PRESS	$3,361	1988
INKJET MARKING	$26,078	1988
DITMCO FIXTURES	$82,869	1988
DITMCO FIXTURES	$28,048	1989
SUB-TOTAL	$142,094	1988
	$28,048	1989
FURNITURE COST		
WORKSTATIONS	$13,908	1988
SUB-TOTAL	$13,908	1988
AUTOMATIC TEST EQUIPMENT (ATE) COST		
TRANSFORMER ATE	$176,168	1988
SUB-TOTAL	$176,168	1988
COMPUTER COST		
OVEN MONITOR	$5,216	1988
SUB-TOTAL	$5,216	1988
	$337,386	1988
	$28,048	1989
TOTAL CAPITAL COST	$365,434	

	GROSS COST	YEAR EXPENSED
EXPENSE COST		
NON-RECURRING EXPENSES		
TRAINING		
	$25,000	1988
	$15,000	1989
SUB-TOTAL	$40,000	
PROCESS MODIFICATION		
	$18,000	1988
	$2,000	1989
SUB-TOTAL	$20,000	
ATE PROGRAMMING		
	$10,000	1988
SUB-TOTAL	$10,000	
	$53,000	1988
	$17,000	1989
TOTAL NON-RECURRING COST	$70,000	
TOTAL CAPITAL AND NON-RECURRING	$435,434	
RECURRING EXPENSES ANNUAL MAINTAINANCE	$9,500	

Figure 14.3-1 Project 87 Expenditure Schedule

PROJECT 87 CASH FLOW SUMMARY
($000)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	TOTAL
Capital	$337.385	$28.048	$0	$0	$0	$0	$0	$0	$0	$0	$0	$365.433
Non-Recurring Expense	$53.0	$17.0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$70.0
Recurring Expenses	$0	$9.5	$9.5	$9.5	$9.5	$9.5	$9.5	$9.5	$9.5	$9.5	$9.5	$95.0
Savings	$50.336	$230.404	$308.459	$400.754	$454.472	$528.562	$611.038	$694.500	$771.590	$828.491	$698.563	$5,577.169
Depreciation	$37.331	$69.120	$56.614	$44.288	$34.785	$26.936	$26.238	$27.022	$19.946	$12.628	$10.525	$365.433

Figure 14.4-1 Project 87 Cash Flows

SECTION 15

IMPLEMENTATION PLAN

The implementation plan for ITM Project 87 initially developed out of an earlier review of factory requirements and the recognition of a need to initiate modernization activities within the FM & TS Production area. Project 87 concentrated attention on improvements which could be made in assembly and test methods within the FM & TS Chassis and Transformer Production areas. The major objectives of ITM Project 87 were to mechanize manual operations and provide automated testing beyond methods currently in use. That, coupled with flexible workstations emphasizing ergonomic factors, is projected to provide significant economic benefit within the production area.

Since the equipment and facilities proposed for acquisition are readily available from several vendors, implementation can be accomplished within a relatively short period (approximately six months) and will be paced by the availability of physical facilities.

15.1 Implementation Plan Activities

Implementation of ITM Project 87 activities is depicted in the Plan Schedule (Figure 15.1-1). *Since the equipment can be accommodated within* the existing production area, acquisition can commence upon receipt of project approval. The improvements scheduled for ITM Project 87 include the following:

- Transformer ATE
- Transformer Marking Equipment
- Pneumatically powered tools with automatic torque control
- Specifically designated chassis area workstations
- Temperature monitoring of ovens
- Orbital/radial headforming in chassis area

The availability of factory floor space will allow installation of the improved product flows as well as the planned operational parameters for the improved equipment.

ITM Project 87 implementation will take place in three basic phases:

Phase	Activity
I	Program Planning
II	Acquisition, Installation, and Training
III	Operation and Validation

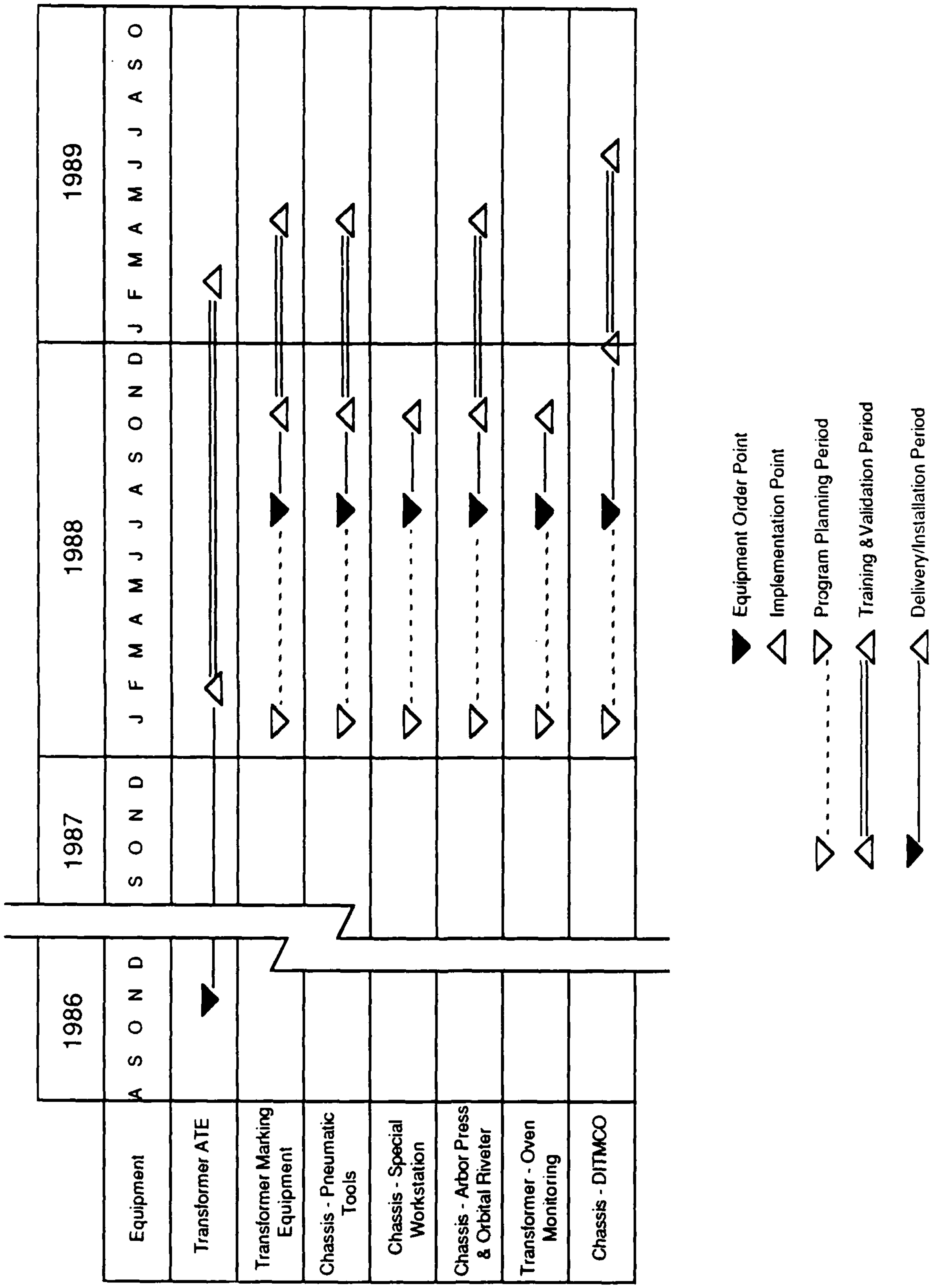


Figure 15.1-1 Project 87 - Implementation Plan

15.2 Phase I - Program Planning

During this phase, all documentation relating to purchasing of the equipment and/or software should be finalized. This will permit immediate initiation of purchase orders upon project approval. Also, planning can continue in terms of identifying assemblies and processes which will be affected and preliminary layouts can be prepared incorporating process modifications.

15.3 Phase II - Acquisition, Installation, and Training

Upon placement of orders, physical preparations can commence. Since equipment leadtimes are relatively short, installation should begin occurring before the mid-point of this period. This will permit training to start and verification of the process alterations previously outlined.

Sufficient time is available to establish stable equipment locations which fit into revised areas and product flows and make adjustments in processes and methods which more effectively integrate the new equipment.

Prior to installation at Honeywell, all software systems will be validated at the respective vendors. All parameters which are customized to Honeywell's requirements will be functionally demonstrated before delivery.

15.4 Phase III - Implementation and Validation

Depending on the respective equipment, implementation is projected to occur either in the third or fourth quarter of 1988. It is assumed that all necessary documentation associated with the scheduled build of principal models will be completed prior to the start of this phase. This will permit an accurate measurement of the benefits of each improvement and validation of the project savings.

Since the implementation of nearly all the modifications in ITM Project 87 impact direct labor performance, the principal validation in the "To-Be" organization will be derived from the "Foreman's Cost Control" records on a month-by-month basis. Additionally, time studies evaluating selected standards may be conducted to validate projected values. Revised paybacks can then be estimated with the resulting "live" data.

SECTION 16

PROBLEMS ENCOUNTERED AND HOW RESOLVED

Problem: Availability of space for ATE Central facility to be located with FM & TS area upon project implementation.

Solution: Chassis area was combined with the relocated transformer facility inside the clean room area.

Problem: Translating various FSO marketing projections of future revenue into growth figures applicable to FM & TS.

Solution: Figures were ultimately subjected to a process of review and scrutiny to ascertain those actually applicable to FM & TS Production.

Problem: Preliminary designs, while technically correct, did not reflect FM & TS preferred operational mode.

Solution: Subsequent designs were modified in a "working meeting" atmosphere so as to contain a maximum number of features desired by the operational personnel who would be implementing and using them.

Problem: Large quantities of parts related data presented a significant data reduction task to derive usable summaries.

Solution: Large data matrices were developed to integrate product description, operation, standards, and quantity data. This enabled accurate and comprehensive summaries to be developed.

Problem: Multiple locations were potentially available for future operations necessitating significant relayout efforts.

Solution: Area elements were entered into CAD database allowing easier update and relayout as revisions and relocations were proposed.

Problem: Significant amounts of tabular data developed and continually modified to reflect current rates, times, and quantities. This was potentially a large clerical task.

Solution: Data was linked and manipulated via powerful spreadsheet programs thus minimizing clerical effort.

SECTION 17

AREA FOR FUTURE CONCERNS/DEVELOPMENT

Future Concerns

- As implementation of Factory Data Collection (FDC) is considered and initiated, attention should be given to providing only those data elements which are necessary for specific area functions to be available in that area. This will reduce the "clutter" of data which could potentially impede the performance of the system. This, essentially, is the essence of hierarchically linking work centers, cells, stations, etc. so that each node has the key resources necessary to accomplish its task.

- Equipment has been proposed for this project in which capabilities exist for future inclusion in local factory networks. This will facilitate future factory modernization. It is important that any automated equipment under consideration be viewed as necessarily including this capability.

Future Development

- Any replacement equipment should have the capability to interface or network so that data can be exchanged and configuration can be controlled.

- Any future transformer winding equipment installed should have computerized functions so that set-up and operation is standardized and repeatable.

- FM & TS should continue to advance the requirement for "design for manufacture" to facilitate future cost reductions.

- Continuous evaluation of equipment coming into the marketplace will uncover price-performance "breakthroughs" that signal a cost effective solution to earlier, uneconomic alternatives.

- Work area arrangements should be sensitive to product volume and models to take advantage of the largest potential savings.